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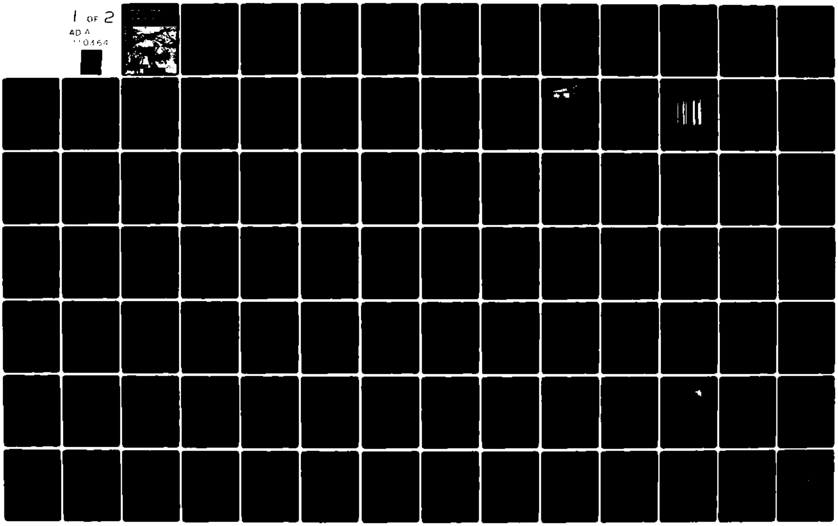

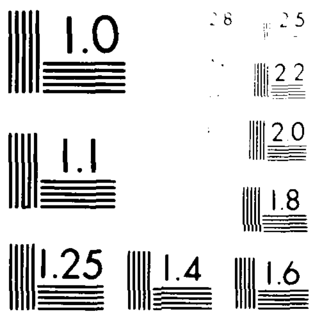
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GRAND FORKS – EAST GRAND FORKS URBAN WATER RESOURCES STUDY

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PLAN FORMULATION APPENDIX

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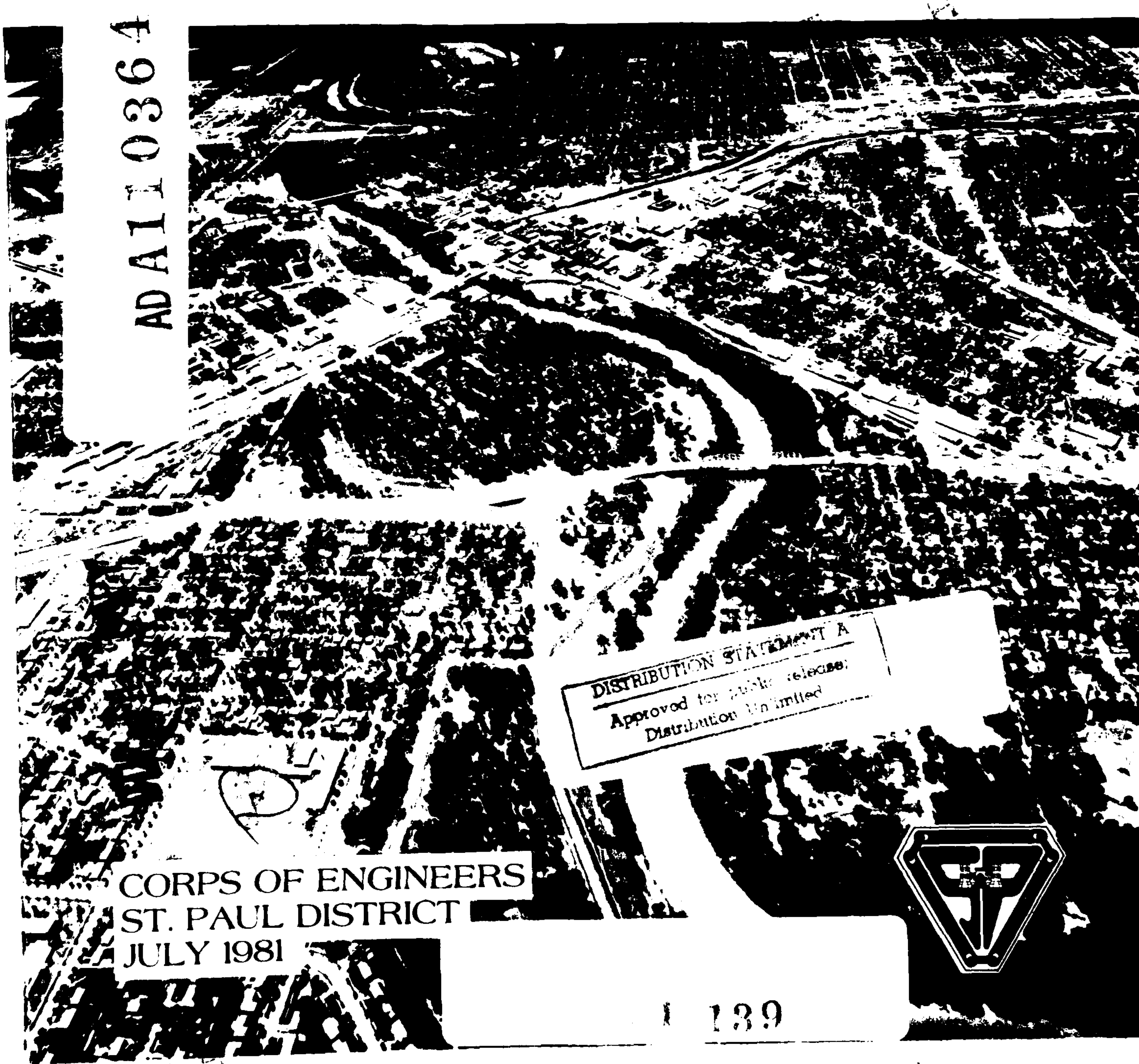

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The goal of the Corps of Engineers Urban Study Program is to provide planning assistance to local interests in a variety of water resource areas, some not within the traditional Corps areas of responsibility. The St. Paul district conducted this study in a cooperative effort with local, state and federal agencies. Primary attention was given to flood control, water supply and wastewater management; supporting investigations addressed recreation and energy conservation. This volume

The Plan Formulation Appendix summarizes the speciality appendices.

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addressing flood control, water supply and wastewater management problems identified in the study area and the supporting public involvement program.

PREFACE

The Corps of Engineers' Urban Study Program is aimed at providing planning assistance to local interests in a variety of water resource and related land resource areas, including water supply, wastewater management, flood control, navigation, shoreline erosion, and recreation. In areas of traditional Corps responsibility (such as flood control), the Corps may implement and construct projects shown in the urban study to be feasible. In other areas (such as wastewater management), Corps involvement carries only through the planning stage; findings are turned over to local interests for incorporation into their broad urban comprehensive planning effort. Implementation is at the discretion of local interests in conjunction with appropriate State and Federal agencies.

The St. Paul District, Corps of Engineers, conducted the Grand Forks-East Grand Forks (GF/EGF) Urban Water Resources Study, which was a cooperative effort between local, State, and Federal agencies. The GF/EGF urban study spanned a time of transition in the Corps' urban study program. In mid-1978, directives were issued deleting the third and last stage of urban studies. At that time, the second stage of the GF/EGF urban study was nearing completion, but commitments for stage 3 studies had been made to local interests and involved State and Federal agencies. Therefore, the GF/EGF urban study was allowed to proceed to stage 3.

During the first stage, the 14-township study area was selected, broad topical problems to be addressed (water supply, wastewater management, and flood control) were identified, and a "plan of study" was developed. The plan of study outlined the general approach the study would follow. During stage 2, the topical problems were broken down into explicit problem areas. Investigators formulated a broad array of alternatives to resolve the study area's problems. The alternatives were evaluated to eliminate those which were not suitable or cost effective. The stage 3 study examined in detail those alternatives that passed the stage 2 screening. Alternatives were reassessed to determine their respective cost effectiveness and environmental/social impacts.

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This particular document is 1 of 11 constituting the GF/EGF urban study report:

Summary Report
Background Information Appendix
Plan Formulation Appendix
Water Supply Appendix
Wastewater Management Appendix
Flood Control and Urban Drainage Appendix
Flood Emergency Plan for Grand Forks, North Dakota
City of East Grand Forks, Minnesota, Civil Defense Flood Fight Plan
Energy Conservation and Recreation Appendix
Public Involvement Appendix
Comments Appendix

The Plan Formulation Appendix summarizes the specialty appendixes addressing flood control, water supply, and wastewater management problems identified in the study area and the supporting public involvement program. The iterative planning process is discussed, including:

- Identification of the water and related land resource problems, issues, needs, and concerns in the study area.

- Development of planning objectives.

- Formulation of alternative solutions to the study area's problems.

- Assessment and evaluation of impacts of the alternative plans.

- Comparison of selected alternative plans.

- Conclusions and recommendations regarding the relative efficacy and implementability of the viable alternatives.

TABLE OF CONTENTS

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TABLE OF CONTENTS (CONT)

TABLES

FIGURES

FIGURES (CONT)

PLAN FORMULATION APPENDIX

SUMMARY

EAST GRAND FORKS FLOOD CONTROL

East Grand Forks, Minnesota, is subject to severe flood damages from periodic flooding by the Red River of the North and Red Lake River. The city has no permanent flood protection; however, emergency levees were constructed along the alignment of an authorized levee project originally studied over 20 years ago. The authorized project and two modifications were evaluated in stage 2. Economic feasibility was shown for the authorized plan and one modification at the interest rate in effect during the original study. Two additional structural plans were formulated for developing areas north and south of the authorized project. Neither plan was economically justifiable under current interest rates.

The authorized levee project and modifications will be reassessed in detail under the Corps postauthorization study program. A flood emergency plan of action was prepared to assist East Grand Forks in better organizing the city's flood fight response.

GRAND FORKS FLOOD CONTROL

Grand Forks, North Dakota, is subject to severe flood damages from periodic flooding by the Red River of the North and English Coulee. Protection against Red River floodwaters is provided by a permanent 1-mile-long Corps-constructed levee and floodwall. The city also relies on timely response by government agencies to impending flood emergencies. The city maintains two emergency levees constructed and improved during recent flood fights.

In stage 2, 10 flood damage reduction alternatives - 6 nonstructural and 4 structural - were examined to assess economic feasibility and environmental and social impacts. On the basis of the screening of alternatives during stage 2 and subsequent discussions with local interests

and consulting engineers involved in the flood control studies, eight plans were evaluated during stage 3 - six structural and two nonstructural. These include two levee/floodwall layouts along the Red River, a road raise barrier protecting one neighborhood from the Red River, two closure/pumping station plans on English and Belmont Coulees, diversion of Red Lake River floodwaters, and evacuation/flood proofing in selected reaches along the Red River and tributary coulees.

Three alternatives were found to merit further consideration - flood proofing and evacuation in the English Coulee and Belmont Road/Belmont Coulee areas of the city and a closure structure/pumping station near the mouth of English Coulee. It was recommended that further analyses be transferred to the Corps' small flood control continuing authority (Section 205 of the 1948 Flood Control Act, as amended) to expedite final studies and possible construction. At this writing, a Section 205 study has already been initiated for the English Coulee alternatives; the Belmont Road/Belmont Coulee investigation will be conducted as a separate Section 205 study.

The feasibility of English Coulee alternatives depends highly on possible flood control improvements being considered for the upper coulee watershed by the Soil Conservation Service (SCS). These improvements include a dry dam to attenuate the coulee's peak flows and diversion ditches to route floodwaters around the city. The Corps will continue coordinating closely with the SCS during the Section 205 studies.

A flood emergency plan of action was developed in cooperation with the city to help better organize Grand Forks' flood fight and evacuation operations.

GRAND FORKS URBAN DRAINAGE

Grand Forks' stormwater drainage problems are related to the flat topography and are compounded by continuing urban development which alters the natural drainage and infiltration and, consequently, overloads the

existing natural and man-made urban drainage system. In conjunction with the urban study's flood control investigation, the Corps prepared an urban drainage master plan for the developing areas within the city's jurisdiction. Two alternatives were considered. Features common to these alternatives include:

- A closure structure near the mouth of English Coulee to prevent flooding from Red River backwater. A pumping station would handle runoff from the coulee and Legal Drain 18 during high stages on the Red River.

- An east-west ditch south of the city to convey waters directly to the Red River that normally must be carried by English Coulee.

The two alternatives differ in that one plan would provide storm sewers and drainage ditches capable of handling the runoff projected for 2030. The second (recommended) plan would temporarily store excess runoff to reduce peak discharges. Storage facilities could assume a variety of forms (for example, parking lots, permanent ponds, and dry depressions normally used for recreation). The reduced discharges would reduce the sizes of sewerlines and ditches. The recommended plan could be implemented in stages as development occurred. The city would provide a storm sewer/ ditch network based on current runoff requirements; developers would have to provide temporary storage facilities to keep runoff at predevelopment levels.

Further study of the urban drainage master plan should be coordinated with the SCS. The SCS's dry dam/diversion scheme for the English Coulee watershed would greatly reduce the flow entering the city.

WATER SUPPLY

Grand Forks and East Grand Forks use the Red and Red Lake Rivers to supply municipal water to urban residential, commercial, and most industrial users and the Grand Forks Air Force Base. A few firms have separate facilities drawing water from these same sources. Three rural water supply

associations provide potable water to small communities and individual consumers. Two of the three systems obtain their water from nearby aquifers. Information on the third was not available for this report. Two other communities share an independent well field. Several industries and other water users draw nonpotable well water for various purposes.

Stage 2 studies concluded that the groundwater sources of the two rural water supply associations on which information is available should provide sufficient supplies of good quality water through 2030. Conclusions were not possible regarding the third association and independent water users. However, the stage 2 report recommended that all three associations and other self-supplied water users continue to supply their own needs rather than join a regionalized system.

Stage 3 studies included "low-flow" analyses of the Red and Red Lake Rivers to determine drought severity and frequency in relation to projected water needs in and upstream of the urban study area. These analyses showed the surface water supply (including river flows plus in-channel storage behind Grand Forks' and East Grand Forks' low head dams) was adequate to meet the 50-year design event through 2030. This conclusion eliminated the need for further consideration of:

- Flow augmentation from the Garrison Diversion project.(1) Political and environmental problems had already delayed any likelihood of a Garrison interbasin transfer of waters into the Red River basin for many years.

- Groundwater sources. Studies had already shown that recharge rates for aquifers in the area were too small to meet the urban area's needs.

- Additional in- or off-channel storage.

(1) The lack of need for Garrison water at Grand Forks-East Grand Forks cannot be arbitrarily extrapolated to other water users in the Red River basin.

The stage 3 findings showed that the most cost-effective approach in the long run is for Grand Forks and East Grand Forks to combine their water supply and treatment systems about 2005. For the short term, the cities should continue to expand and refurbish their respective plants to meet growing needs. For example, Grand Forks' current maximum daily demand already exceeds the treatment plant's rated capacity; expansion is needed now, but room for expansion could mean removing nearby residences or plant relocation. East Grand Forks' plant capacity is sufficient for projected demands until 2005, but operation will have to be increased from the present 8 to 10 hours per day to 24 hours per day.

Water conservation could reduce demands up to 10 percent even in non-drought periods and would be cost effective because of the savings in the supply and treatment facility size and operating costs. Conservation practices would require a serious commitment by citizens, industry, and local government, but could be implemented without significantly hindering development potential or the quality of life.

Treatment processes cannot be finalized until the Environmental Protection Agency promulgates final requirements for advanced surface water treatment. Preliminary evidence shows Red and Red Lake River waters may not need advanced treatment to meet the proposed regulations, but standards may become more stringent.

A drought emergency plan of action was developed to conserve water in a serious shortage. The plan identifies responsibilities of Federal, State, and local authorities that would be involved. The plan proposes a five-stage response to increasingly severe drought conditions ranging from voluntary, not particularly inconvenient measures to highly restrictive, mandatory measures that could be enforced via monitoring and penalties.

WASTEWATER MANAGEMENT

All major wastewater treatment facilities in the study area are lagoon systems; a few small communities and rural subdivisions and individual rural residents have septic tanks and tile drain fields. Typically, wastewater is stored in the lagoons over the winter and released into the rivers to coincide with high springtime flows.

Studies of the Grand Forks wastewater treatment system conducted under Section 201 of Public Law 92-500 showed that lagoon expansion and reconstruction of the effluent discharge line would provide satisfactory performance through the year 1990. Projections suggest East Grand Forks' lagoon system could become organically overloaded about 1995.

Other significant lagoon systems serve the American Crystal Sugar plant in East Grand Forks, the Air Force Base, and the communities of Thompson, Manvel, and Emerado, North Dakota. Stage 2 studies showed the lagoons serving the latter four were marginal to inadequate. Even though their effluent was meeting their National Pollutant Discharge Elimination System permit specifications, they do not meet proper design criteria and/or are overloaded.

In stage 2, wastewater treatment alternatives included:

- Maximum regionalization of systems to handle most communities and major industries.

- Maximum use of existing facilities.

- Combinations of some facilities (partial regionalization).

Alternative types of facilities were examined to meet various degrees of treatment to be decided by future legislation and/or regulations of agencies such as the Environmental Protection Agency (EPA). Possible wastewater system improvements range from merely increasing the capacity of the existing plant to maintain the present degree of effluent control to using advanced mechanical treatment processes or land application of lagoon effluent to achieve zero discharge of critical pollutants.

The stage 2 studies showed that regionalization was not cost effective because of the long transmission systems required. Separate facilities based on lagoon systems were shown to be the least costly alternative for point source effluent regardless of the level of treatment. However, because the zero discharge criteria would require extensive tracts of land for lagoon effluent disposal, if this degree of treatment is required, further studies would be needed to compare advanced mechanical treatment (which is not land intensive) with land application.

Since existing plans for future wastewater treatment of point source effluents already are based on the most cost-effective alternative - lagoon systems - further consideration in stage 3 was considered unnecessary. Stage 3 focused on intermittent point and nonpoint stormwater pollution sources. The most serious situation in the study area is related to overflows from Grand Forks' combined sewers which serve the core of the city. Problems include:

- A public health threat from combined sewer discharges into Grand Forks' raw water supply pooled behind a low-head dam in the Red River of the North.

- Public health threats from sanitary sewer backup into basements.

- Extra hydraulic load on the lagoon system from stormwater runoff.

Grand Forks had already begun a sewer separation program before the urban study's findings were available. Stage 2 studies confirmed that sewer separation, perhaps in combination with source control (e.g., street sweeping), was the preferred method of solving the problem. However, in stage 3, a number of solutions were reconsidered to:

- Ensure that sewer separation was the most cost-effective approach.

- Qualify the city for possible Federal financial assistance by preparing the report in concert with the EPA to meet the step 1 requirements of the Construction Grants Program.

The area served by combined sewers was divided into subareas, and alternative source control measures, sewer separation plans, and effluent treatments were evaluated to determine the most cost-effective approach.

The stage 3 results reaffirmed sewer separation as the most cost-effective solution. At this writing, the EPA has approved the urban study's findings and recommendations and has provided step 2 funding which the city has used to contract with consulting firms for plans and specifications. This project has been placed on the State's priority list, but it appears that only about half the Federal funds needed to complete step 3 (construction) will be available in the near future.

THE REPORT

The Grand Forks-East Grand Forks Urban Water Resources Study was divided into two elements:

- Major Studies - Flood Control, Water Supply, Wastewater Management

- Supporting Studies - Social and Environmental Inventory, Demographic Study, Institutional Study, Leisure Time Analysis, Thermography Study.

Specialty appendixes were prepared for each major study. A Background Information Appendix was prepared to provide a profile of the study area and identify the desired future conditions and specific problems, issues, needs, and concerns. The supporting studies expanded on the existing profile of the study area where necessary to provide additional information useful when assessing and evaluating plans formulated for each major study. An Energy Conservation and Recreation Appendix combined the results of the thermography study and leisure time analysis. The Public Involvement Appendix discusses the means by which interested participants - on the local, State, and Federal levels - were integrated into the planning process.

This document, the Plan Formulation Appendix, was prepared to summarize the specialty appendixes. It presents significant study area problems, issues, needs, and concerns; the planning objectives; the formulation of alternative plans; and the design of component systems. It also assesses and evaluates impacts, discusses implementation arrangements, and summarizes interaction of the public involvement program with the planning process.

The final report will include four other documents:

- Flood Emergency Plan for Grand Forks, North Dakota.
- City of Grand Forks, Minnesota, Civil Defense Flood Fight Plan.
- Comments Appendix which presents the views of interested parties based on their review of the urban study's various reports.
- Summary Report which summarizes the Plan Formulation Appendix for the nontechnical reader.

The first two reports outline the steps local interests should take to prepare for and conduct a flood fight or emergency evacuation.

The following diagram shows the report components and their completion schedule.

GRAND FORKS - EAST GRAND FORKS URBAN WATER RESOURCES STUDY

SCHEDULE OF DOCUMENTS

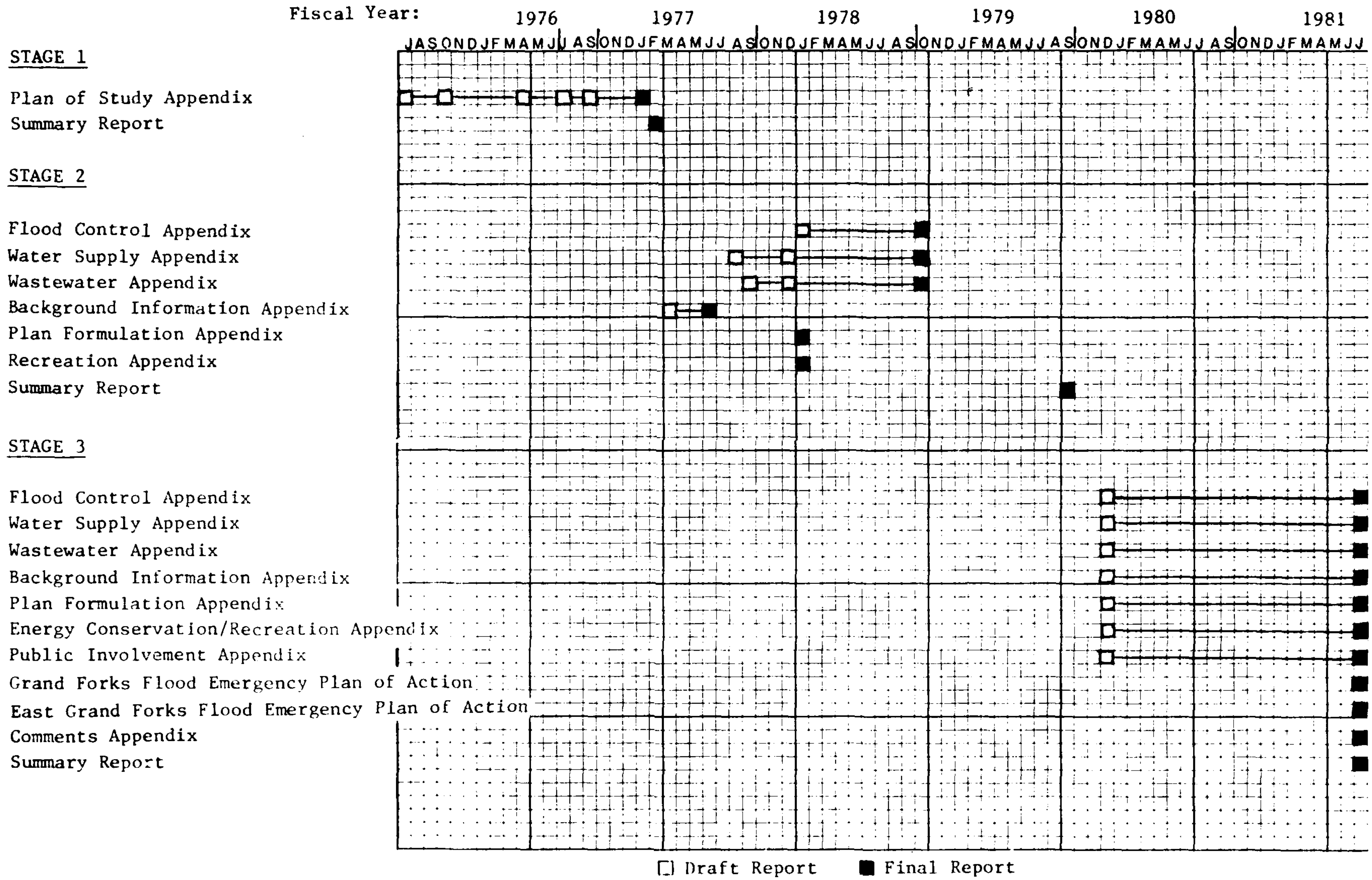


FIGURE 1

THE STUDY AND STUDY AREA

The Grand Forks-East Grand Forks Urban Water Resources Study is a cooperative Federal, State, and local planning effort to develop viable alternative water resource plans for flood control, water supply, and wastewater management within the study area for short-range (20-year) and long-range (50-year) planning periods.

The study area encompasses 14 townships - Grand Forks, Huntsville, Rhinehart, and Sullivan Townships of Polk County, Minnesota, and Blooming, Brenna, Chester, Falconer, Ferry, Grand Forks, Mekinock, Oakville, Rye, and Walle Townships of Grand Forks County, North Dakota. Major population centers are the cities of Grand Forks and East Grand Forks and the Grand Forks Air Force Base near Emerado. Figure 2 locates and defines the study area.

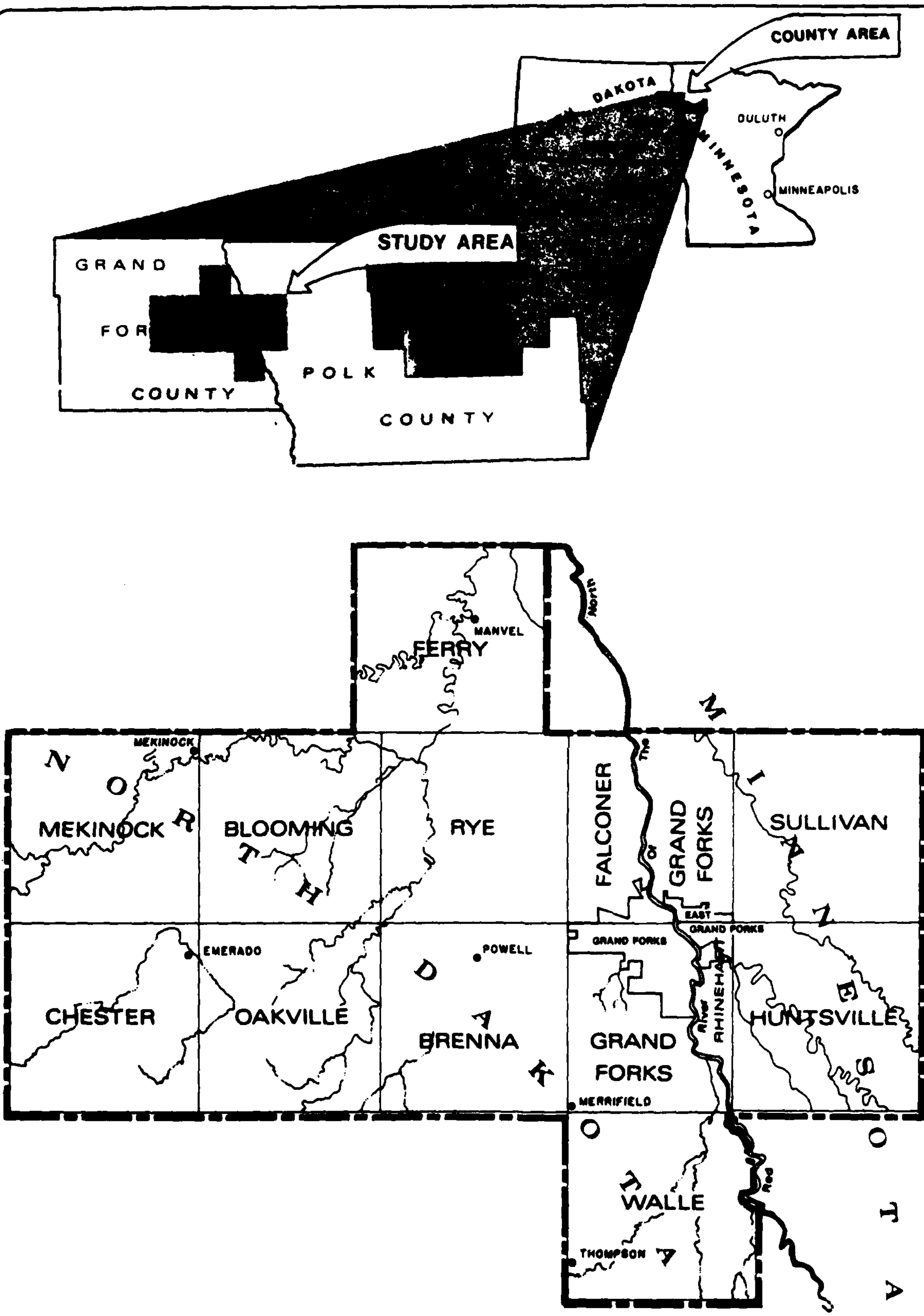


FIGURE 2 - Study Area

FLOOD CONTROL

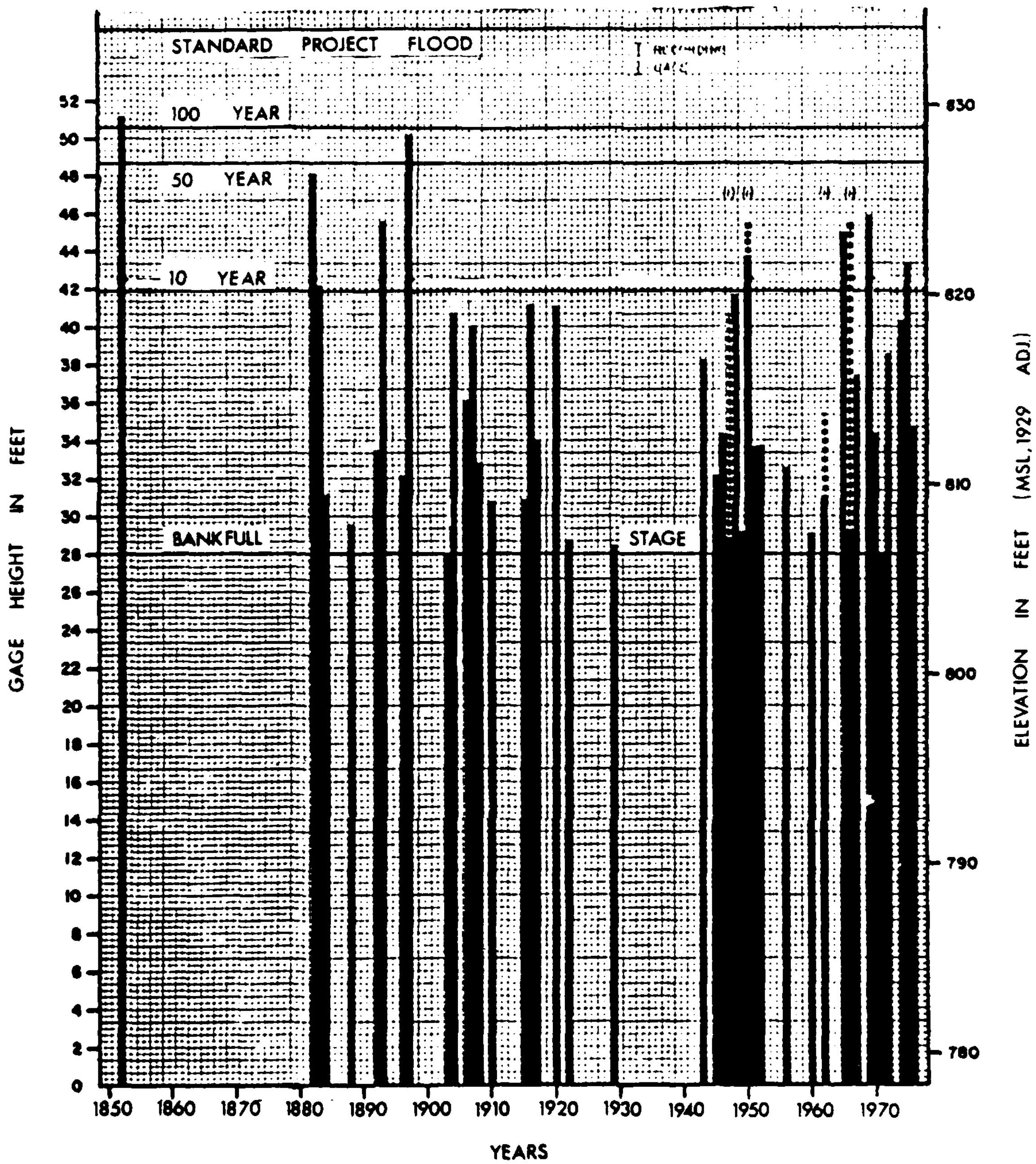
GENERAL

Within the study area, only Grand Forks and East Grand Forks were identified as having flood problems. Grand Forks and East Grand Forks lie on the west and east banks, respectively, of the Red River of the North approximately 298 miles above the mouth of the river at Lake Winnipeg, Manitoba, Canada. The drainage area of the Red River at Grand Forks-East Grand Forks is 26,300 square miles. The Red Lake River bisects the community of East Grand Forks and intersects the Red River upstream of the commercial areas of both cities. The Red Lake River drains approximately 5,700 square miles in Minnesota. English Coulee is another important tributary of the Red River. The coulee drains approximately 100 square miles in North Dakota and flows through Grand Forks to its confluence with the Red River just downstream of the city.

The floodplains of these three watersheds experience frequent flooding in the study area. Figure 3 identifies floods above bank-full stage at the U.S. Geological Survey gage on the Red River in Grand Forks. Variations in shading on the graph indicate more than one flood during the year. The horizontal lines on the graph identify the various levels of flooding based on historical records.(1)

---

(1) The St. Paul District recently reanalyzed the frequency-discharge relationship for the Red River at Grand Forks in light of revised U.S. Geological Survey discharge estimates for major floods in the 19th century and the frequency of major floods in recent years (including back-to-back "floods of the century" in 1978 and 1979). The 10-, 50-, and 100-year crest elevations shown on figure 3 have been readjusted in accordance with the Corps' new relationship. <u>All references to frequency-discharge and frequency-elevation relationships in this report are based on the "old" frequency-discharge relationship.</u> Future Corps studies will be based on the new relationship. The new relationship increases the discharge (hence the elevation) for any given flood frequency - for example, the 100-year event increases from 89,000 cfs (cubic feet per second) to about 106,000 cfs and from elevation 828.7 to about 830.3.



RED RIVER OF THE NORTH

(1) VARIATION IN SHADING ON THE BAR GRAPH INDICATES MORE THAN ONE FLOOD DURING THE YEAR

(2) U.S.G.S. GAGE ON LEFT BANK 500 FEET DOWNSTREAM FROM DAM AT RIVERSIDE PARK IN GRAND FORKS AT MILE 295.7. GAGE ZERO, ELEVATION 778.35.

URBAN WATER RESOURCES STUDY

GRAND FORKS, NORTH DAKOTA

FIGURE 3

FLOODS ABOVE BANKFULL STAGE

ST. PAUL DISTRICT CORPS OF ENGINEERS

Principal factors contributing to flooding include the very flat river slope, northward drainage, channel obstructions, and increasing agricultural drainage and diking. The low river slope of one-half foot per mile and resultant low velocities retard drainage from the area. The flow of surface runoff from southern areas into still frozen river reaches at times results in ice jams and increased river stages. Bridges over the river obstruct flood flows at the higher flood stages. Local interests strongly feel that improved agricultural drainage (e.g., of wetlands) has increased runoff to the extent that flooding is more frequent and serious. Farmer-constructed dikes downstream have significantly reduced floodplain storage with resultant higher flood stages.

The area is subject to spring floods caused mainly by snowmelt runoff and summer floods from heavy rains. An exception, the 1965 flood, was caused principally by heavy widespread rainfall over deeply frozen soils. A list of the 10 largest floods of record together with corresponding flood crest heights and discharges is given in table 1.

Table 1 - 10 largest flood discharges, Red River of the North at Grand Forks, North Dakota

Order of magnitude	Date of crest	Gage heights (feet)(1) Stage	Elevation	Estimated peak discharge (cfs)
1	10 April 1897	49.3	827.65	85,000
2	26 April 1979	49.81	827.16	82,000
3	18 April 1882	46.3	824.65	75,000
4	4 April 1966	45.55	823.90	55,000
5	11 April 1978	45.73	824.08	54,200
6	12 May 1950	45.5	823.85	54,000
7	16 April 1969	45.69	824.04	53,500
8	24 April 1893	43.8	822.15	53,300
9	17 April 1965	44.92	823.27	52,000
10	24 April 1975	43.27	821.62	45,000

(1) Gage zero = 778.35 (1929 adjustment).

The specific planning objectives for formulation of plans for flood control in the study area include:

1. Contribute to the reduction of recurring flood losses in the Grand Forks and East Grand Forks area to relieve the economic and psychological burdens on society and local residents during the 1980-2030 planning period.

2. Contribute to the maintenance and enhancement of the environmental quality of riverine woodlands and wetlands in the study area to increase wildlife and recreational values during the 1980-2030 planning period.

3. Contribute to development of a plan for effective floodplain management for the 1980-2030 planning period to ensure responsiveness to local desires, compatibility with other ongoing planning efforts, and acceptability to area residents.

4. Contribute to the development of a flood emergency plan of action to ensure efficient local reaction to serious flood threats during the 1980-2030 planning period.

EAST GRAND FORKS FLOOD CONTROL

East Grand Forks is protected to a limited degree by a relatively unreliable system of emergency levees. The levees were built by the Corps of Engineers with local cooperation during the 1965, 1966, and 1969 emergency flood fights and subsequently were turned over to the city. In the absence of permanent flood protection, a large part of the East Grand Forks urban area is subject to direct (surface water) or indirect (sewer backup) flooding. With the emergency levees in place, flood damages of over $2 million were averted in 1965, 1966, 1969, and 1978; damages prevented in 1979 exceeded $5 million. A 1975 summer flood which did not allow enough time for an effective flood fight caused about $700,000 in damages.

On the basis of a 1953 Definite Project Report prepared by the St. Paul District, Congress authorized a levee plan for East Grand Forks.

Until recently, the authorized plan was not studied further because the city would not guarantee that it would meet the local cooperation requirements. However, following the several serious floods in the late 1960's, the city signed an official agreement indicating willingness to participate in the project. The emergency levees generally follow the alignment of the levees authorized in the 1953 Definite Project Report (figure 4). East Grand Forks has entered the regular phase of the Federal Insurance Administration flood insurance program adopted 23 September 1977.

Scope of the East Grand Forks Flood Control Study

The stage 2 flood control studies for East Grand Forks:

- Reviewed the adequacy and economic feasibility of the authorized levee plan.

- Examined the feasibility of increasing the degree of protection offered by the authorized plan.

- Evaluated flood protection for areas of newer development upstream and downstream of the authorized project.

Further postauthorization studies of the authorized plan and variations are being conducted as a Corps Phase I General Design Memorandum, not as part of the urban study. Therefore, the discussion in this report related to the authorized levee plan reflects stage 2 findings.

The scope of the stage 3 flood control study for East Grand Forks was limited to developing a flood emergency plan of action to ensure that the city's future flood fights will be effective and coordinated with other involved units of government.

Emergency Levee System

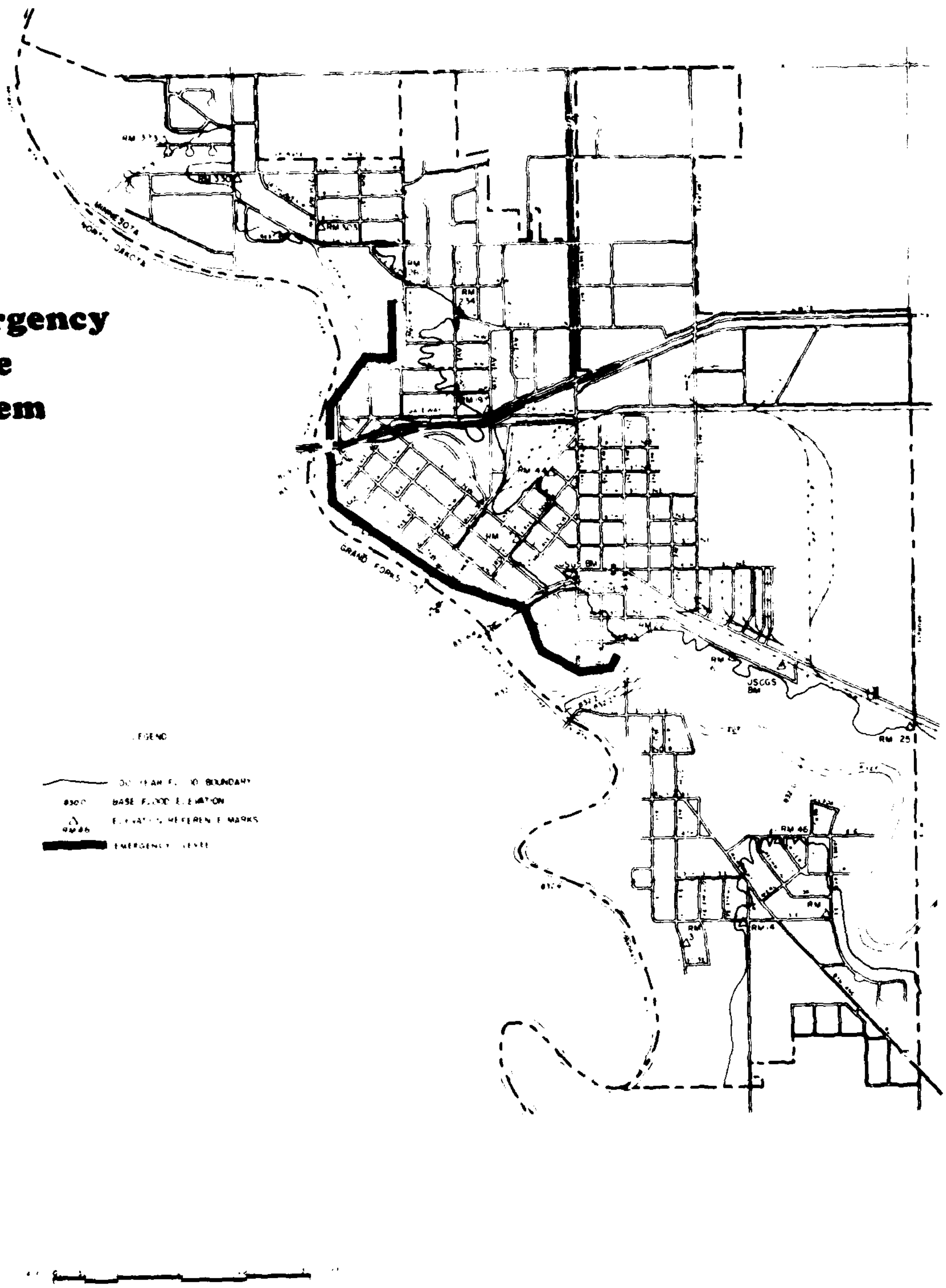


FIGURE 4

East Grand Forks

Minnesota

Problems - Issues - Needs - Concerns

Several problems have been identified related to inadequacies of the emergency levee system:

- Lack of interior drainage facilities - Lack of permanent pumping stations to handle interior drainage requires emergency pumping of seepage waters and normal runoff trapped behind the levees during a flood.

- Poor soil stability along existing levee alignment - A weak layer of lacustrine deposits has resulted in severe slides and subsidence of portions of the emergency levee system. A damaging slide undergoing continued movement is just north of Sixth Avenue NW. The slide has caused subsidence of the levee and damages to adjacent residential yards. Another slide area is located in the commercial parking lot just downstream of DeMers Avenue.

- Flood protection less than the authorized project - The level of flood protection of the emergency levees is in question. The levees were raised during the 1979 flood fight. Following the flood, the extra fill was blended into the levee cross section, but the levees were not returned to their pre-1979 configuration. The levees were resurveyed in conjunction with the Phase I study but, at the time of the urban study's involvement, the net effect of the levee raise/regrading was not certain. Therefore, <u>comments in this report related to levee heights are based on pre-1979 conditions.</u> The pre-1979 levee profile would contain about the 4-percent (25-year) flood with 3 feet of freeboard. Table 2 relates the freeboard provided by the emergency levee to floods of various frequencies. The emergency levee without further modification would provide no freeboard for an estimated flow of 80,500 cfs, frequency of 1.45 percent (69-year return period), and elevation 828.0. Less frequent flood events would overtop the emergency levee and cause devastating damage.

Table 2 - Flood protection levels

Level of protection in percent (recurrence interval)	Estimated flow (cfs)	Estimated elevation (feet)	Estimated elevation plus 3 feet of freeboard (feet)	Freeboard provided by emergency levee (feet)
4 (25-year)	59,000	825.0	828.0	3.0
2 (50-year)	74,000	827.3	830.3	0.7
1.5 (67-year)	80,000	827.8	830.8	0.2
1 (100-year)	89,000	828.7	831.7	Overtops
0.2 (500-year)	130,000	834.1	837.1	Overtops

• Inadequate design and construction of existing levees - The term "emergency levees" reflects the haste in which the levees were built to provide emergency flood protection. Accordingly, the emergency levees do not satisfy Corps design criteria and construction procedures. The Corps views emergency levees only as a means of reducing flood damages during the event for which they were constructed. Emergency levees do not provide reliable protection for future events and usually are not credited with reducing average annual flood damages. In the event of a major flood, emergency levees are very susceptible to failure.

• False sense of security - The daily visibility and continued flood protection offered by the emergency levees build local confidence in the system and create a false impression that adequate protection is present or will be forthcoming in another emergency. Therefore, no local plan of action had been developed to upgrade the emergency levees during nonflood periods or to cope with the situation should the emergency levees be overtopped.

• Further encroachment of emergency levees on private property - Raising and widening of the emergency levee system during a flood emergency in the Sixth Avenue NW slide area may require relocation of several garages and possible loss of 23 residential backyards.

• Easements - The emergency levee between Sixth Avenue NW and 10th Avenue NW has only a maintenance easement to the top of the emergency levee, with access only from either end. Additional easements would be needed in a flood emergency or for future construction.

Even with the emergency levee system, East Grand Forks remains subject to major economic flood losses, threats to public health and safety, and possible loss of life. Measures are needed to provide a level of protection commensurate with Corps design and construction standards and existing local floodplain and flood insurance programs and to maintain an up-to-date flood emergency plan of action.

Formulation of Alternative Flood Barrier Plans

- The existing emergency levee system does not provide adequate flood protection. The emergency levees are deficient not only in design and construction, but also in height and extent. Retention of the emergency levee was not considered to be a desirable or viable option and was not evaluated further.

- The authorized project plan (plan A) would protect against a flood with about a 1.5-percent chance of occurring during any given year. The plan includes raising and widening 7,600 feet of emergency levee and replacing part of the existing levee with 1,500 feet of concrete floodwall between Sixth Avenue NW and the Burlington Northern railroad bridge (figure 5). Interior drainage works, a ramp over the levee at North Fourth Street, and necessary utility relocations would be provided.

- Modified authorized plan (plan B) would provide the same degree of protection as the authorized levee. The modified plan differs from the authorized plan in that a concrete floodwall would be used in place of an earthen levee along a revised alignment riverward of First Street NW between Sixth and 10th Avenues NW. Plan B (figure 6) was developed because field observations indicated that the slide area was still active and that realignment or raising of the emergency levee was not practical without relocation of several garages and the loss of 23 residential backyards. Plan B requires complete acquisition of these 23 residences and relocation of the residents, but most likely avoids the unstable foundation conditions.

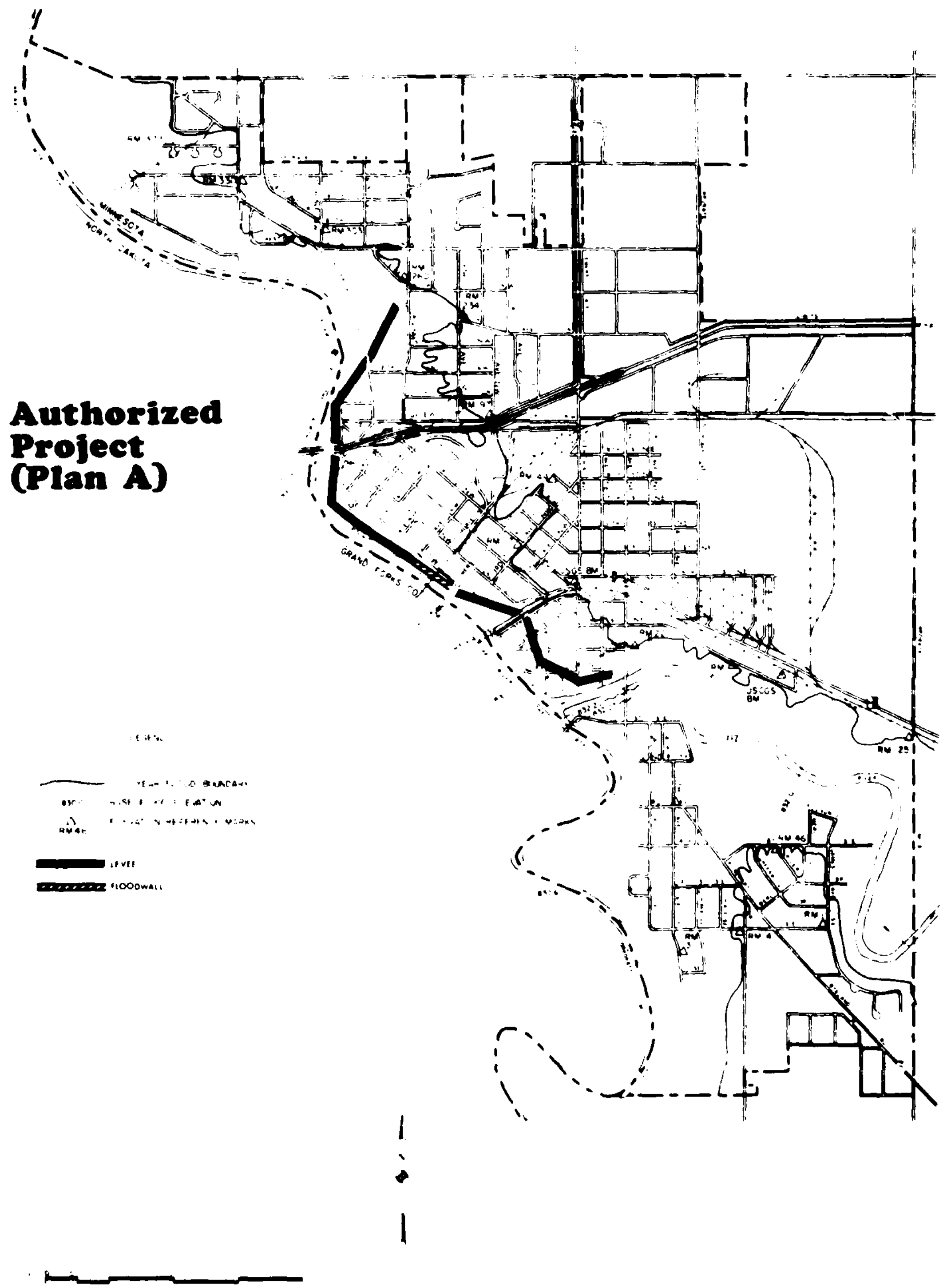


FIGURE 5

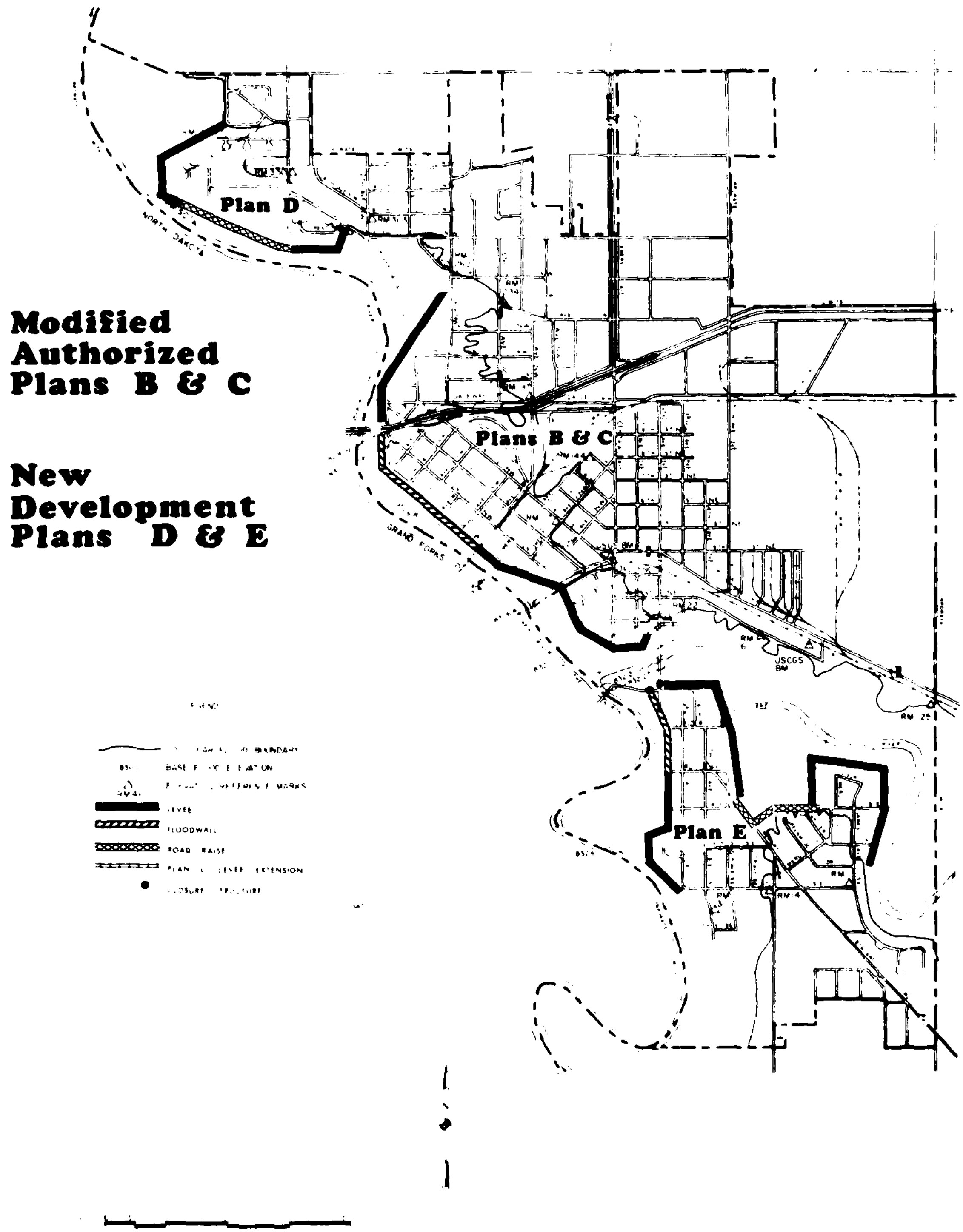

Plan D
Modified
Authorized
Plans B & C
Plans B & C
New
Development
Plans D & E
Plan E
USCGS BM
LEVEE
FLOODWALL
BASE FLOOD ELEVATION
East Grand Forks
Minnesota

FIGURE 6

• Modified authorized plan C would protect against a flood with a 1-percent chance of occurring during any given year. The plan involves raising modified authorized plan B approximately 1.6 feet and lengthening it about 1,200 feet (figure 6).

• New development plan D would provide protection against a flood with a 1-percent chance of occurring during any given year to new development areas north of the authorized project limits. This plan (figure 6) includes 1,800 feet of raised road and 2,800 feet of levee together with needed utility relocations and interior drainage works.

• New development plan E would protect against a flood with a 1-percent chance of occurring during any given year to new development areas on Minnesota Point, which is across the Red Lake River from the authorized project. This plan (figure 6) includes 8,000 feet of levee, 1,400 feet of concrete floodwall, 3,100 feet of road raise, and two closures (Minnesota Street and Second Avenue SE) together with the necessary utility relocations and interior drainage works.

Impact Assessment and Evaluation for Flood Barrier Alternatives

• Economic Impacts - Table 3 summarizes the estimated costs and benefits of each alternative. Total Federal and non-Federal first costs were estimated based on October 1977 price levels. The authorized plan and its modifications were evaluated using a 100-year economic life and both the authorized interest rate (3 1/4 percent) and the interest rate in effect during the stage 2 studies (6 5/8 percent). The new development plans were evaluated only at 6 5/8 percent. Average annual benefits were derived from field surveys conducted in September 1977.

Table 3 - Comparison of costs and benefits, East Grand Forks flood barrier alternatives

Item	Plan A Authorized Plan		Plan B Modified Authorized Plan		Plan C Modified Authorized Plan w/1-Percent Protection		New Development Plan D	New Development Plan E
	3 1/4%	6 5/8%	3 1/4%	6 5/8%	3 1/4%	6 5/8%	6 5/8%	6 5/8%
First costs								
Federal	$7,047,000	$7,243,400	$8,026,000	$8,226,000	$8,400,500	$8,610,200	$1,300,000	$5,766,000
Non-Federal	494,600	510,700	2,289,000	2,340,000	2,350,600	2,408,700	395,000	398,000
Total	7,541,600	7,754,100	10,315,000	10,566,000	10,751,100	11,018,900	1,695,000	6,164,000
Average annual costs								
Federal	238,800	480,100	271,900	545,900	284,600	571,500	86,200	382,600
Non-Federal	31,800	49,900	91,600	170,300	94,300	175,500	31,000	39,200
Total	270,600	530,000	363,500	716,200	378,900	747,000	117,200	421,800
Average annual benefits (1)	316,000	316,000	316,000	316,000	422,000	422,000	29,000	122,000
Benefit-cost ratio	1.2	0.6	0.9	0.4	1.1	0.6	0.2	0.3

(1) Average annual benefits do not consider local employment and future damage growth. By adding local employment and future benefits attributable to the reduction of damage to future growth, it is possible that a marginally infeasible project might prove to be economically feasible.

The benefit-cost ratios indicate two economically justifiable plans: the authorized plan A (67-year) and the modified authorized plan C (100-year). These plans were feasible using the authorized interest rate and October 1977 price levels for construction and assuming "existing conditions" damages without projected future damages. By adding benefits attributable to the reduction of damages to future growth, it is possible that the modified authorized plan B might also be feasible at the authorized interest rate.

No plan was economically feasible at the 6 5/8-percent interest rate. However, no consideration was given to average annual benefits resulting from local employment and future damage growth. If these factors are included, economic feasibility might be found even at the higher interest rate. Flood protection for the areas north and south of the authorized plan limits was not economically feasible.

The authorized plan would require the initial expenditure (first costs) of $7,047,000 and $494,600 in Federal and non-Federal money, respectively. In addition, local interests would bear annual operation, maintenance, and major equipment replacement costs of about $15,000.

The modified authorized plan C (100-year) would require the initial expenditure (first costs) of $8,400,500 and $2,350,600 in Federal and non-Federal money, respectively. Local operation, maintenance, and replacement costs would be $14,700 annually.

- Environmental Impacts --- The authorized plan (67-year) would require the removal of 40 to 50 large trees with related loss of native wildlife. The levee would be located away from the wooded riverbank and little impact on these areas is anticipated. Aesthetic conditions would be expected to remain the same as those with the existing emergency levee.

The modified authorized plan C (100-year) would be essentially the same as the authorized plan (67-year) with a slightly greater loss in aesthetics because of the 1.6-foot raise of the levee.

• Social Impacts - The authorized plan (67-year) would increase public health and safety as a result of added flood protection in the developed area.

The modified authorized plan C (100-year) would sharply reduce the incidence of flooding and increase public health and safety even beyond the authorized plan (67-year). An additional 53 flood-prone structures would be protected with this plan. A significant adverse effect would be the removal and relocation of 23 residences and relocation of the occupants due to the revised alignment. It is anticipated that relocation assistance payments would offset moving costs and that the purchase of similar dwellings would be subject to local housing market conditions.

Flood Emergency Plan of Action

The seriousness of the flood threat to East Grand Forks is unquestioned as are the inadequacies of the existing emergency levee system. However, the prospects for permanent flood protection as an outcome of postauthorization studies are uncertain. The authorized plan and one of the modified plans appear economically justifiable at the originally authorized interest rate; however, reviews by congressional and administration committees concerned with fiscal matters may prompt a recommendation against the project unless feasibility can be shown at current interest rates. Also, the impact from the Corps' recent revision of the frequency-discharge relationship of the Red River at Grand Forks has not been factored into the analysis. The probable result will be higher levees, hence higher costs, but also greater benefits because of the added protection. The net effect on economic feasibility is uncertain at this time.

Even if feasibility is shown, several years might pass before additional studies and plans and specifications are completed and before construction is authorized and funds are appropriated. Therefore, for at least several years and perhaps the foreseeable future, the city will continue to rely on emergency flood fighting. Furthermore, despite the city's commendable and effective flood fighting as exemplified in the 1979 spring flood, the directors of the flood fight note a need for improved organization and documentation if less experienced people are in charge during future floods.

Therefore, the need for a flood emergency plan of action was evident. If a permanent levee system is eventually constructed, the emergency plan could be revised accordingly. Extreme flood events from extraordinary combinations of meteorological and antecedent moisture conditions can and have exceeded the design capability of permanent flood barriers in various parts of the country. Therefore, the city should update the plan of action and remain prepared to upgrade the permanent flood protection if needed and to evacuate if the permanent protection fails.

The objectives of the flood emergency plan of action were to:

- Help the city use its flood-fighting resources in the most effective manner.

- Learn from past flood fights - take advantage of the trial and error process of previous years, anticipate recurring problems, and avoid repeating unsuccessful efforts.

- Hypothesize possible flood emergency situations that might require actions as yet untried - plan for contingencies so that the response is quick and effective.

- Provide a flexible, evolving manual that could be updated as experience or community changes dictate.

The East Grand Forks Civil Defense Director and the consulting firm which serves as the city's engineers prepared the manual under contract to the Corps of Engineers. The authors also enlisted the aid and input of other individuals involved in leading the city's 1978 and 1979 flood fights.

Items addressed in the manual include:

- Flood fight organizational structure - Respective responsibilities of 23 units handling every aspect of flood fighting from food services to sandbag filling to morgue arrangements.

- Flood emergency center - Location, equipment, communications.

• Cooperating organizations - Responsibilities, functions, and resources of city, county, regional, State, and Federal agencies involved in flood fight and postflood assistance.

• Preflood preparations - Public education on flood insurance, flood proofing, and flood forecasts; inventory and stockpiling of sand, sandbags, pumps; inspection and repair of flood works.

• Conduct of the flood fight - Mobilizing volunteers and equipment, effecting closures, capping storm sewer outfalls, ensuring municipal services, assisting residents' self-help activities, providing protection breakdown contingency plans, developing evacuation plans.

• Postflood activities - Cleanup, estimates of damages and flood fight costs, government assistance.

Summary and Recommendations

Existing emergency levees in East Grand Forks do not provide adequate or dependable flood protection. The city remains subject to major economic losses, threats to public health and safety, and possible loss of life. Consideration must be given to upgrading the emergency levees to provide properly designed and constructed flood protection commensurate with local floodplain and flood insurance programs.

The stage 2 studies showed that authorized plan A (67-year level of protection) and modified authorized plan C (100-year level of protection) would be economically feasible at the authorized (3 1/4 percent) interest rate. The authorized modified plan C represents the more technically feasible plan on the basis of current design criteria and poor soil stability along the authorized alignment and is recommended for further analysis during postauthorization (Phase I General Design Memorandum) studies. Flood protection for new development areas north and south of the authorized plan does not appear to be economically feasible; however, because of the damage potential, consideration should be given to

alternative flood protection measures for these areas. Postauthorization studies might also consider nonstructural measures, such as zoning regulations, land use regulation, and other regulatory measures supplemented by emergency relief measures.

The flood emergency plan of action developed in stage 3 of the urban study should be revised if postauthorization studies result in the construction of permanent flood protection. The city should expedite adoption of the provisions and recommendations in the flood emergency plan of action. Pamphlets and a professionally narrated slide program describing the plan of action's features were prepared during the urban study. These public information tools should be used by the city to ensure residents and flood fighters are fully aware of the features that might apply to them (e.g., emergency evacuation routes). The city could install floodplain information signs in flood-prone areas relating local water levels to predicted U.S. Geological Survey (USGS) gage readings. Census-like information should be solicited from residents to aid in plans involving evacuation and voluntary assistance.

GRAND FORKS FLOOD CONTROL

Grand Forks has emergency levee systems in the Riverside Park and Central Park neighborhoods and a permanent flood control project at Lincoln Park constructed in 1958 by the Corps of Engineers. Grand Forks was subject to major flooding as recently as 1965, 1966, 1969, 1975, 1978, and 1979. However, disasters were averted through flood fighting measures, including the construction of emergency levees. Without emergency levees, flood damages would have approached $1 million in 1966 and 1969 (at October 1977 price levels). A 1975 summer flood which provided inadequate response time for a more effective flood fight resulted in about $500,000 in damages. Damages prevented by the existing emergency levees and the flood fight in 1979 approached $8 million. However, considerable damages were suffered by residences in the English Coulee floodplain and areas subject to poor drainage. A flood event having a 1-percent chance of occurrence in any given year could overtop the permanent and emergency levees and cause over $50 million in damages.

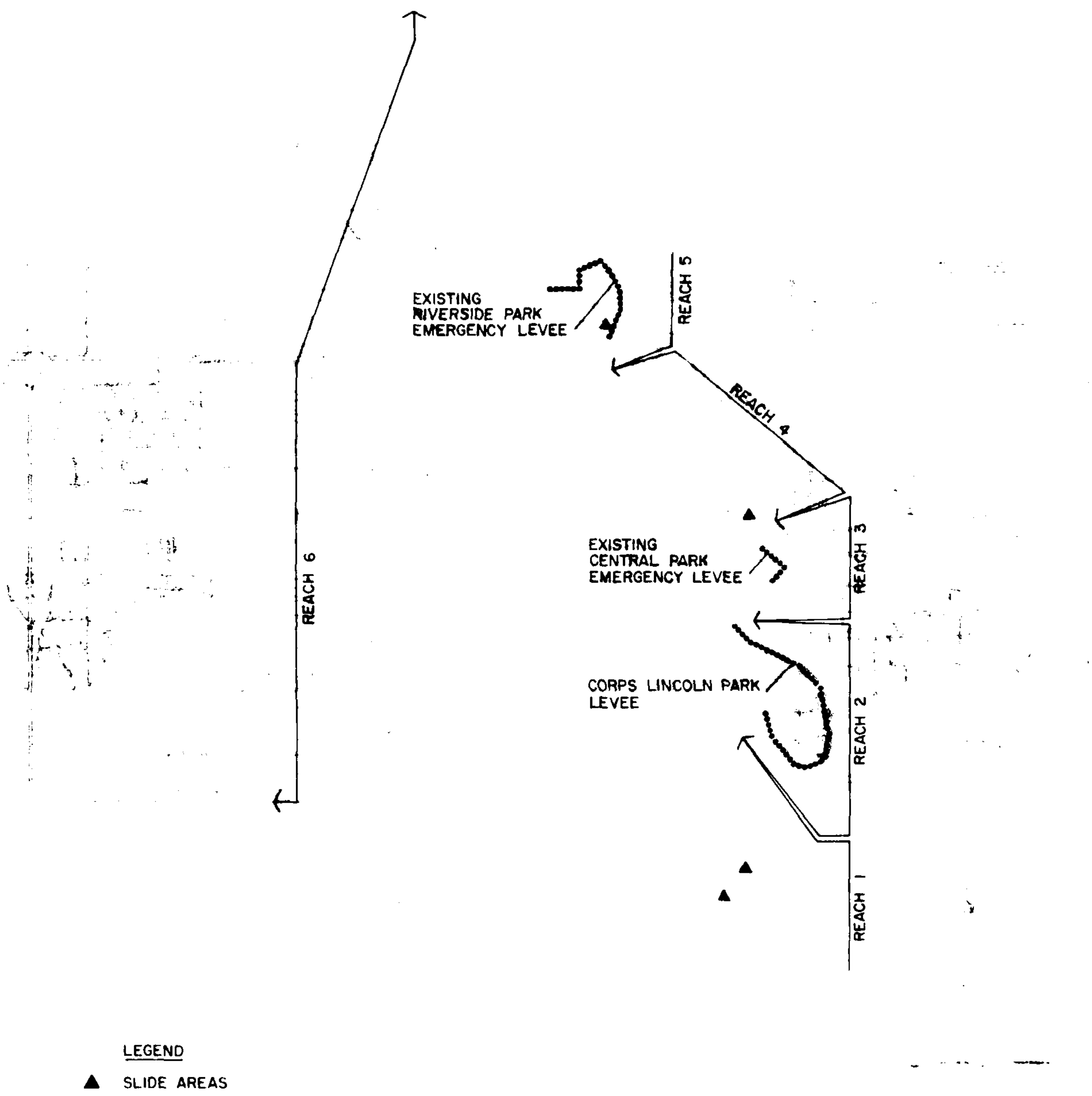
Problems - Issues - Needs - Concerns

At Grand Forks, flooding begins at a Red River stage of about 28 feet at the USGS gage (elevation 806.35) and appreciable flood damage begins at a stage of 35 feet. A large part of the urbanized area is subject to either surface water flooding or sewer backup (figure 7 - see outline of 1-percent flood). A flood with a 1-percent chance of occurrence in any given year would subject one-third of the city (over 2,600 buildings and over 70 square blocks of the downtown section) to direct flooding.

Specific concerns include:

- Permanent flood works provide a relatively low level of protection - The existing permanent flood control project at Grand Forks was completed in 1958 by the Corps of Engineers and consists of a 5,160-foot earthen levee, a 700-foot concrete floodwall, and interior drainage facilities (figure 7). The project was designed to protect the Lincoln Park neighborhood from a 79,000-cfs or 2-percent (50-year) Red River flow with 2 feet of freeboard. However, two factors have lowered this degree of protection. First, soil creep has caused subsidence of the structure over the years. Second, reanalysis of the discharge-frequency relationship was necessary in light of the growing period of record and recurring serious floods in recent years. The net result is a level of protection averaging closer to a 30-year flood. And, as discussed earlier, more current analyses will put the existing level of protection even lower. An occurrence of the 1-percent flood would overtop the levee by more than 1 foot in some spots.

- Poor design and construction of emergency levees and lack of proper interior drainage facilities - The emergency levees were constructed quickly during flood emergencies without due regard for Corps design criteria, including accepted minimum levels of protection in a densely urbanized area. During a major flood, the levees are susceptible to erosion and/or overtopping. The emergency levees were constructed by the Corps of Engineers and turned over to the city of Grand Forks. The Central Park levee (figure 7)



EXISTING FLOOD CONTROL IMPROVEMENTS

FIGURE 7

was constructed during the 1971 flood emergency. The levee is 1,500 feet long with an average 10-foot-top width and 3 horizontal on 1 vertical side slopes and has a maximum height of about 10 feet. The top of the levee corresponds to a stage of 45.8 feet (elevation 824.2 as measured at the USGS gage). The levee lacks interior drainage facilities, requires extremely long sandbag or other methods of closure, and is inadequate in design and construction. The other emergency flood barrier is located in the Riverside Park area between U.S. Highway 2 on the south and Riverside Park on the north (figure 7). This barrier was constructed in 1975 and consists of a 3,450-foot earthen levee and wood plank wall. The 2,800-foot levee has an 8-foot-top width, an average 8-foot height, and side slopes varying from 2 on 1 to 3 on 1 on the riverward side and 3 on 1 to 4 on 1 on the landward side. A 650-foot wood plank wall supported by 8- by 8-inch beams on 6-foot centers constitutes the remainder of the flood barrier. The levee lacks interior drainage facilities and is inadequate in design and construction. In the 1979 flood, a sewerline burst behind the plank wall and four homes were completely flooded; a backup levee saved the rest of the neighborhood.(1)

- False sense of security - The existence of the emergency levees creates a false impression that protection is adequate.

- Unstable foundation conditions - The existing emergency levees are located on or near unstable riverbank areas consisting of a weak layer of lacustrine deposits laid down in glacial Lake Agassiz (figure 7). An active slide, located under the upstream end of the Riverside Park levee, started in 1972. Addition of more emergency levee fill in 1976 increased the rate of movement with subsequent subsidence of the levee and cracking of nearby building foundations. Other slides have occurred in 1946 at the city waterworks and in 1953 at the upstream end of the existing Corps project. A slide area farther upstream at the Elks Club parking lot is active with observed vertical displacement of over 2 feet in the paved parking lot.

(1) After the 1979 flood, the city razed these four homes and the wood plank wall and extended, raised, and realigned portions of the emergency levee.

- Inadequate flow capacity along English Coulee - During the 1979 flood, the Burlington Northern railroad bridge caused nearly 3 feet of head loss during coulee runoff, contributing to serious flooding in the western part of Grand Forks, including the inundation of about 200 residences and accounting for the bulk of the city's flood damages and 1,400 evacuees. Other obstructions, check dams, culverts, and bridges also contributed to a loss of flow capacity.

- Lack of flood fight preparations along English Coulee - During the 1979 flood, coulee runoff resulted in flood stages surpassing the 100-year levels shown in the Grand Forks Flood Insurance Study. The crest arrived with little forewarning, trapping people in their residences and flooding parked cars. No one anticipated direct flooding of this magnitude from English Coulee; the recognized threat was from backwater from high stages on the Red River.

- Urban drainage deficiencies - The flat terrain and poorly defined drainage courses cause overland sheet flow in major runoff events. These problems will worsen as continued urban development destroys natural infiltration and storage areas and results in greater runoff volume and higher peak discharges.

Conduct of Grand Forks Studies

In stage 2, Grand Forks' flood problems were split into two related topics examined in separate studies: Red River of the North flood control and urban drainage problems. Flooding along English Coulee was felt to be primarily a function of backwater from the Red River; its treatment in the flood control study was limited in scope; more attention was given to English Coulee flooding as an urban drainage problem.

In stage 3, however, following the 1979 spring flood when direct flooding from coulee runoff became a major issue, English Coulee was reexamined in both the flood control and urban drainage studies. The focus of the two studies began to blur and merge as the seriousness of the urban drainage problem elevated it to a major flood control concern.

However, for clarity in this appendix and in keeping with the initial sepration of the two topics, the following discussion focuses first on the flood control studies and second on the urban drainage studies.

Flood Control Alternative Formulation

The flood control study area for Grand Forks consists of the Red River of the North floodplain and the English Coulee floodplain within the city limits. To aid in the analysis of flood damage reduction needs, the study area was separated into six reaches (listed below and shown on figure 7):

Reach 1 - South city limits to Almonte Avenue. This reach includes the Belmont Coulee and Belmont Road areas from the southern city limits to near the upstream end of the Lincoln Park levee/floodwall project.

Reach 2 - Almonte Avenue to Seventh Avenue South extended. This reach covers the Lincoln Park levee/floodwall project.

Reach 3 - Seventh Avenue South extended to Minnesota Avenue. This reach includes the Central Park neighborhood and existing emergency levee. The downstream limit coincides with the confluence of the Red and Red Lake Rivers.

Reach 4 - Minnesota Avenue to Seventh Avenue North. This reach covers the downtown business district.

Reach 5 - Seventh Avenue North to Coulee Drive. This reach covers the Riverside Park neighborhood and existing emergency levee.

Reach 6 - English Coulee from the mouth to 17th Avenue South. This reach covers the coulee to the approximate upstream limits of the 100-year flood outline defined by the Federal Insurance Administration's 30 September 1977 Flood Boundary and Floodway Map.

In stage 2, six nonstructural and four structural alternatives were considered. The nonstructural alternatives were formulated for a 100-year level of protection; the structural alternatives were formulated for 50-year, 100-year, and standard project flood protection.

Nonstructural alternatives considered were:

- Flood warning and forecasting services - Flood warning predicts the time and magnitude of a flood so that emergency measures can be taken. Forecasting services for flash floods and spring runoff floods would be provided by the National Weather Service office in Fargo, North Dakota.

- Flood insurance - The flood insurance program established by the National Flood Insurance Act of 1968 makes available specified amounts of flood insurance previously unavailable from private insurers. Grand Forks has complied with the requirements for eligibility in the regular program, and flood insurance is available for structures and contents at actuarial rates.

- Floodplain regulations and practices - Grand Forks has adopted a floodplain zoning ordinance to regulate and manage flood-prone areas. The ordinance establishes zoning districts and restricts uses for each district. The ordinance also requires building permits which take the flood hazard into account and flood proofing certification based on the city's flood proofing code.

- Evacuation and relocation - Permanent evacuation of all flood-prone structures from floodplain areas would involve acquisition of lands by purchase, removal of improvements, evacuation of the population, and conversion of the lands to uses less susceptible to flood damage. Redevelopment areas for displaced residences and businesses (over 2,600 structures) would probably be available west and southwest of the Grand Forks urbanized area.

• Flood proofing - In general, any structure not more than 100 feet within the 100-year flood outline and/or having a first-floor elevation not more than 2 feet below the 100-year water surface elevation was considered for flood proofing - a total of 2,400 residences, businesses, and public buildings.

• Emergency flood fighting and relief activities - When flooding is imminent, Grand Forks would arrange for mobilization of personnel, equipment, and supplies to meet the flood threat. For flood elevations which may exceed the protection provided by existing flood works, additional flood fighting activities may be required, including closures, temporary interior drainage pumping, increasing the existing level of protection, and evacuation. Also, under Public Law 99, Federal assistance is available for emergency flood protection when requested by the city and when the city's available resources have been exhausted.

Structural alternatives considered were:

• Flood barriers - Flood barriers were evaluated for Reaches 1-5; flood barriers were considered impractical for Reach 6 (English Coulee) because of the widely scattered flood-prone property. The flood works consisted of appropriate combinations of floodwalls, road raises, closures, ramps, interior drainage measures, and necessary relocations. All flood barriers would provide 3 feet of freeboard over the design flood level.

• Diversion channel - A diversion channel constructed around the west side of Grand Forks would carry all flood flows in excess of the Red River's bank-full capacity. A movable gate diversion structure would be placed across the Red River channel. The 13.7-mile grassed channel would have an average depth of 20 feet and a bottom width of over 1,400 feet for the standard project flood. The floodway would cross major highways at five points, railroad tracks at four points, and numerous county, township, and private roads. Local drainage ditches and English Coulee would require closures at their intersections with the diversion channel.

- Reservoir storage - A recent unpublished study by the St. Paul District, Corps of Engineers, indicates that a reservoir on the Red Lake River could reduce the 100-year flood crest by 1 foot at Grand Forks. Studies of authorized reservoirs on the Wild Rice and Sheyenne Rivers indicate additional stage reductions of one-half foot each at Grand Forks.

- Channel modification - This work would include widening both banks of the Red River, cutting off meanders, deepening the channel, and raising bridges to provide clearance for floodwater, debris, and ice.

During impact assessment and evaluation of the above measures, the following conclusions were reached:

- The only structural plan demonstrating economic feasibility was to increase the level of protection provided by the existing permanent levee/floodwall to 50 years. Benefits and costs of the reservoir and channel modification plans were not analyzed in detail; however, the Red Lake River reservoir was found economically infeasible in another study and reservoirs on the Wild Rice and Sheyenne Rivers would not be operational for years. Channel modification was found to have so little hydraulic effect as to obviously not justify the costs and environmental impacts.

- Several nonstructural measures (flood forecasting, emergency flood fighting, flood insurance, and floodplain regulations) would be partially effective in that they could provide warning, temporary flood works, mitigation for flood victims, and a means for preventing further unwise floodplain development. However, these measures would not alone or in combination provide a comprehensive solution to Grand Forks' flood problems.

On the basis of stage 2's findings and subsequent coordination with local interests, eight measures were studied in stage 3:

- Increase level of protection of existing permanent levee/floodwall - This plan was the only economically feasible structural plan in stage 2.

- Construct a permanent flood barrier to protect the Riverside Park neighborhood - This alternative is a variation on the one found economically infeasible in stage 2; the four houses flooded by the 1979 flood would be razed and the timber floodwall in this area replaced by a realigned levee or floodwall.

- Construct a closure structure/pumping station near the mouth of English Coulee - This plan was briefly addressed in stage 2, but not evaluated. It would prevent backwater flooding from high Red River stages and handle coincidental coulee runoff with the pumping station.

- Divert Red Lake River floodwaters around the urban area via Grand Marais Coulee - This plan was recommended for study in the stage 2 report.

- Combine evacuation and flood proofing in selected areas of Reaches 1 and 6 - Stage 2 found total evacuation or total flood proofing of all structures in the floodplain to be economically infeasible, but recommended further consideration in certain areas.

- Construct closure structure/pumping station at Belmont Road crossing on Belmont Coulee - This plan is similar in intent to the English Coulee facility. The North Dakota State Water Commission developed the plan being evaluated.

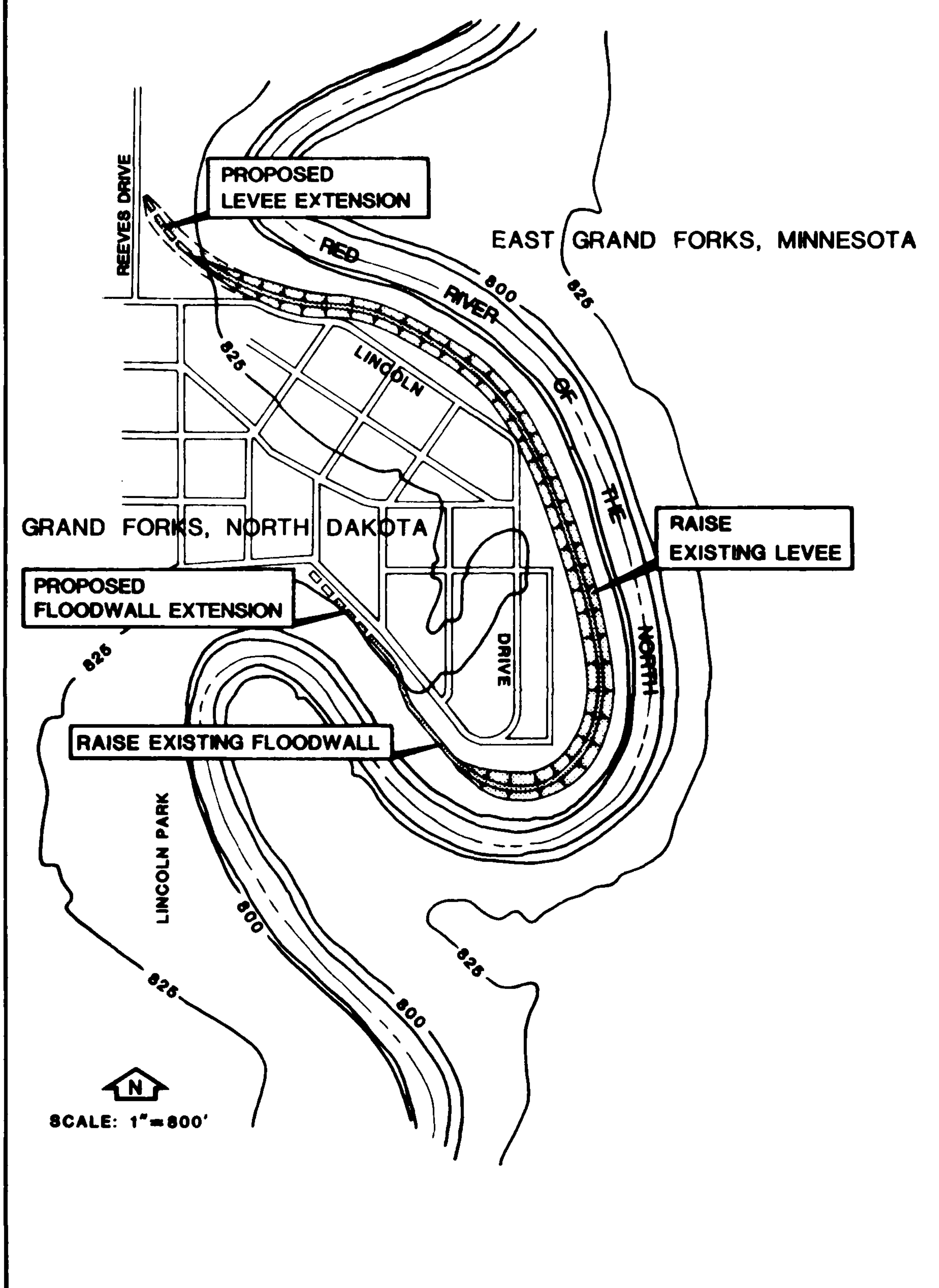
- Raise Belmont Road to prevent overtopping by Red River floodwaters - This plan would protect a neighborhood across from Lincoln Park.

- Construct flood barriers along English Coulee - This scheme was considered in stage 2 and felt to be impractical; but, in light of 1979's unprecedented direct flooding from coulee runoff rather than the backwater flooding considered in stage 2, it was felt prudent to reassess this alternative.

Where practical, three levels of protection were considered - 25-, 50-, and 100-year. The stage 2 findings showed no economic feasibility for protection in excess of 50 years; hence, stage 3 focused on protection in the 100-year and under range. Several of these plans had not been evaluated in stage 2; rather, they were developed or recognized subsequent to the main efforts in stage 2. Therefore, the consulting engineer contracted to do the stage 3 studies was directed to initially provide stage 2 rather than stage 3 level of detail, but with improved field data to ensure technically and economically more reliable results. The social and environmental assessment was limited to identification of obvious, debilitating impacts that would in all likelihood preclude eventual implementation. It was intended that, if any alternative passed this early stage 3 screening, a follow-up contract would be awarded for more detailed economic, social, and environmental studies. This plan was later modified and, as discussed below, further studies were recommended for transfer from the urban study to another Corps authority. A brief description of these alternatives follows:

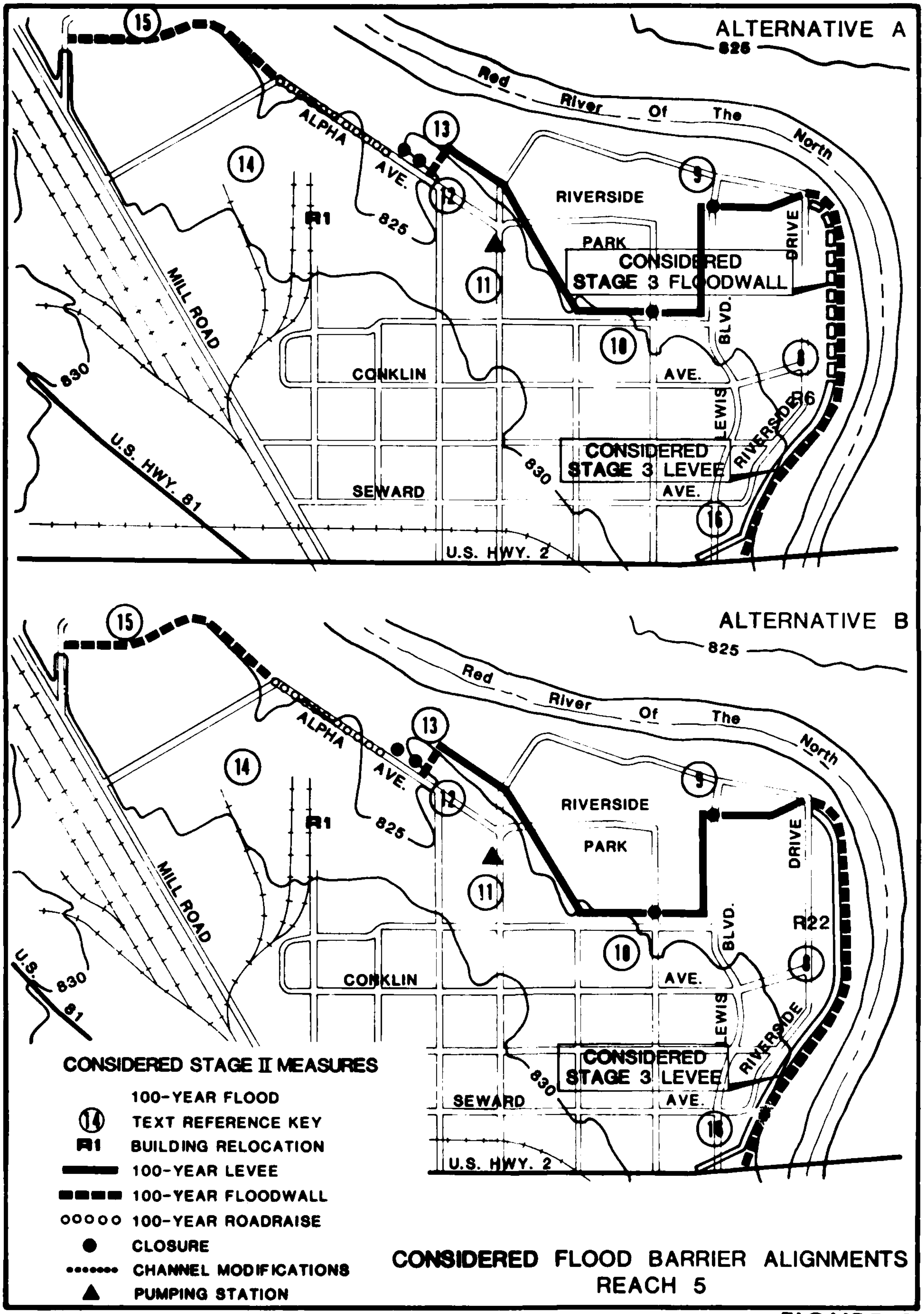
- Increase level of protection of existing permanent levee/floodwall - The existing structure was designed to provide 50-year protection with 2 feet of freeboard. A reassessment shows approximately a 30-year level of protection with 3 feet of freeboard. Topographic surveys showed that adjacent high ground was too low to provide tiebacks to either a 50- or 100-year level of protection with 3 feet of freeboard. The highest practical tieback on the north (levee) end of the existing flood barrier is only about 1.8 feet above the average top elevation of the existing levee; the highest tieback on the upstream (floodwall) end is no higher than the average top elevation of the existing floodwall. The highest practical level of protection is about 47 years. This increase in protection would require levee and floodwall extensions (figure 8), the removal of 2 homes, and landscape changes to 10 other homes.

- Construct a permanent levee to protect the Riverside Park neighborhood - The city's planned acquisition of the four Riverside Park homes flooded in the 1979 spring flood led to consideration of two alternatives to the permanent levee/floodwall scheme evaluated in the stage 2 report (figure 9). One alternative consists of a levee around the entire area;



CONSIDERED REACH 2 FLOOD BARRIER RAISE

FIGURE 8



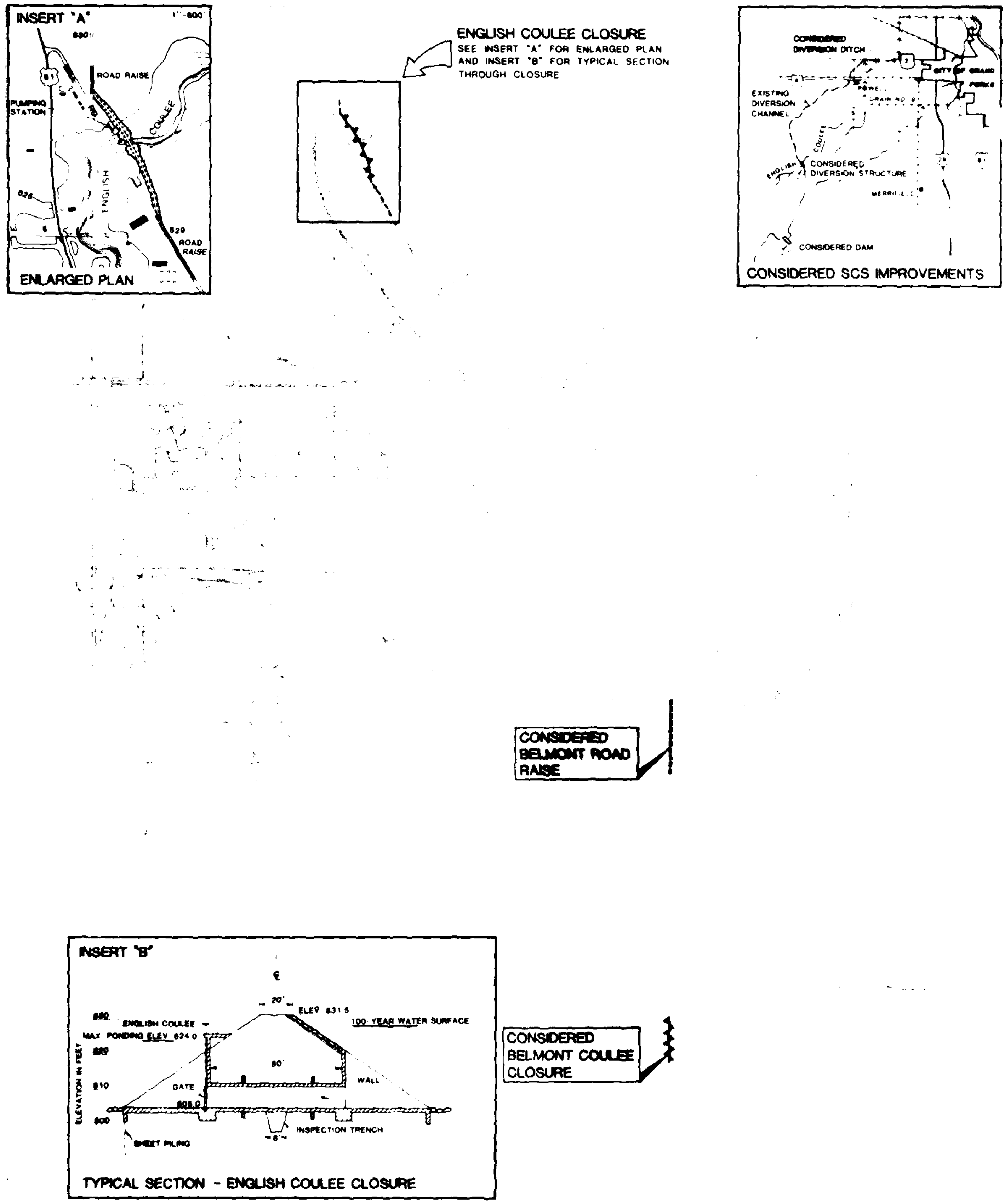
CONSIDERED FLOOD BARRIER ALIGNMENTS
REACH 5

FIGURE 9

this scheme requires the removal of all the homes (22) riverward of Riverside Drive. The other alternative uses a floodwall to reduce the taking of homes to six. Both alternatives would provide permanent interior drainage facilities. These alternatives were evaluated at 50- and 100-year levels of protection.

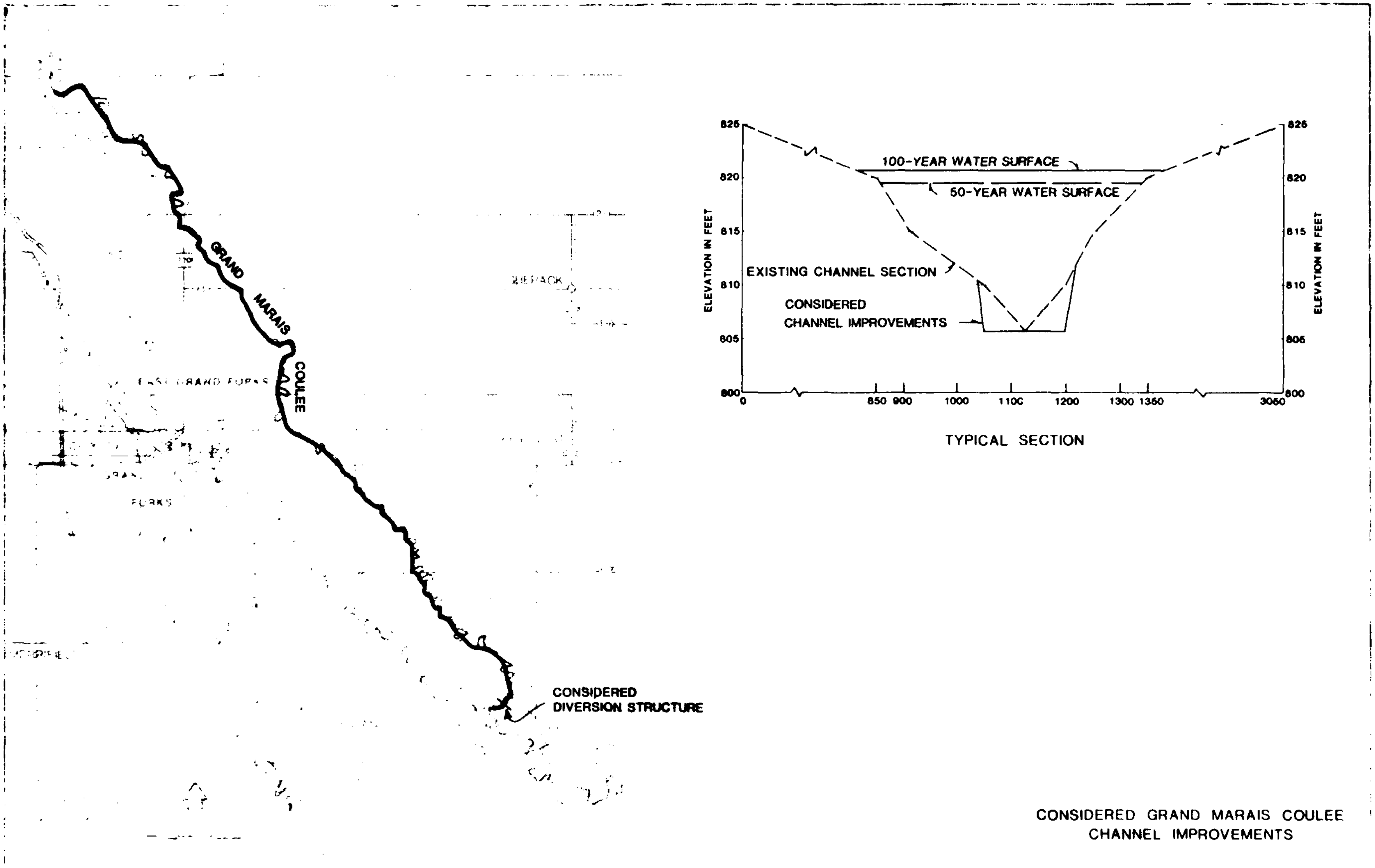
- Construct a closure structure near the mouth of English Coulee - This facility would prevent flooding of properties along the banks of the coulee from Red River floodwaters backing up the coulee. As formulated, the facility would consist of a controlled closure structure located immediately downstream of Mill Road (figure 10) and sufficient pumping capacity to pass coulee flows when the closure structure is closed. The controlled outlet on the closure structure would normally be open to permit gravity drainage of coulee flows. During high Red River stages, however, the outlet would be closed to prevent the intrusion of Red River floodwaters. The pumps would have to handle coulee runoff exceeding the available in-channel storage. Depending on the ultimate fate of various diversion schemes and a dry dam being considered for the upper coulee watershed by the SCS and the Grand Forks County Water Management and Control Board, the 100-year flows down the coulee could range from less than 1,000 to nearly 2,400 cfs. Attenuation of these peak flow rates from the available in-channel storage volume would reduce pumping rates but not enough to offset the need for extremely expensive pumping facilities.

- Divert Red Lake River floodwaters via Grand Marais Coulee - Grand Marais Coulee begins near Fisher, Minnesota, and runs northwesterly about 23 valley miles to its confluence with the Red River about 10 miles downstream of Grand Forks (figure 11). The coulee drains a 275-square mile drainage area. Flows vary from little or no flow during late summer and winter to a projected 3,500 cfs at the U.S. Highway 220 bridge during a 100-year flood. High stages on the Red Lake River can spill over into the coulee drainage at a point about 4 miles downstream from Fisher. Field surveys show these overflows begin when the Red Lake River flow reaches about 13,000 cfs (a 5-year flow). The scheme that was considered would divert 11,500 cfs of the 100-year Red Lake River discharge down the coulee via a fixed crest spillway. Computer studies show the existing coulee channel



CONSIDERED ENGLISH COULEE CLOSURE
(AND BELMONT ROAD ALTERNATIVES)

FIGURE 10

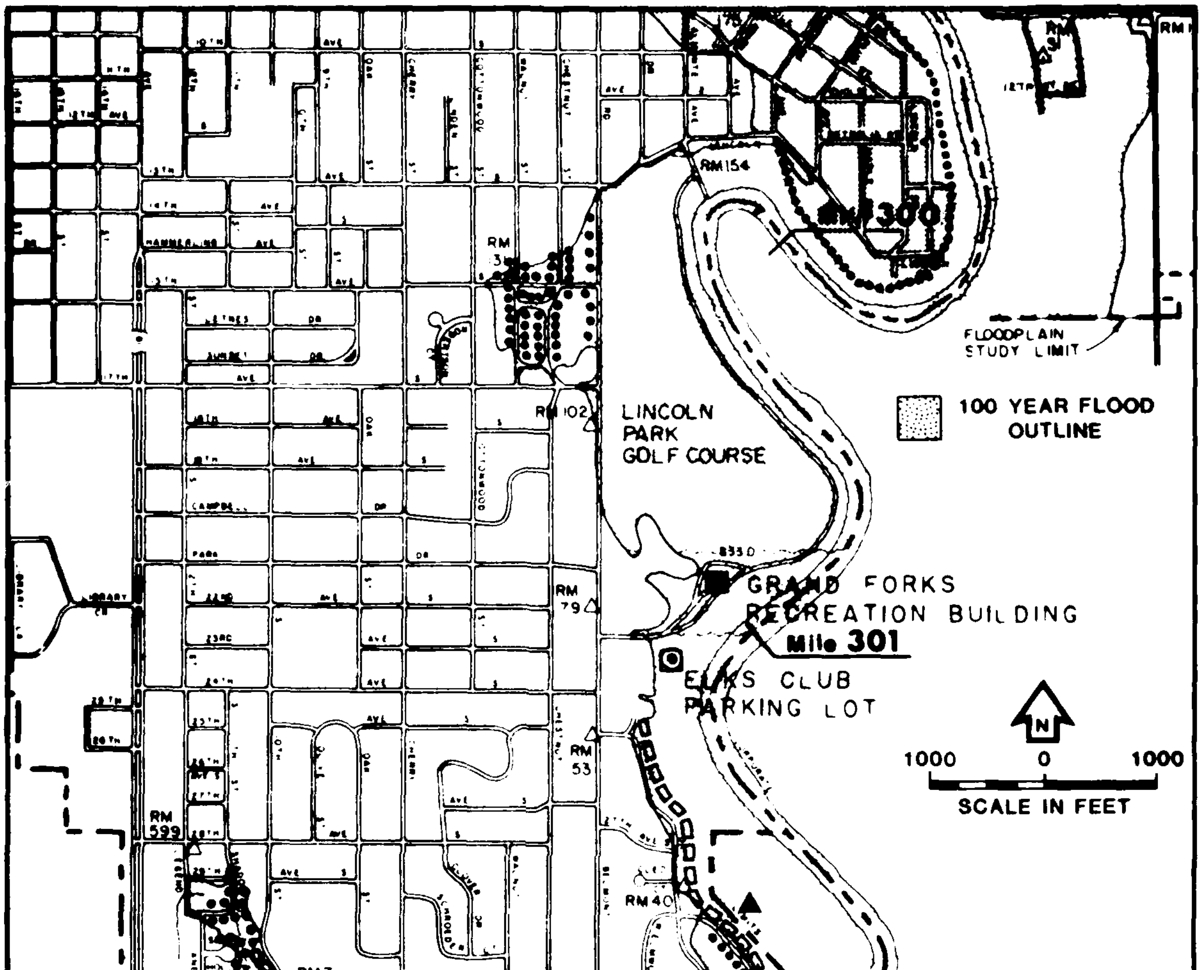


CONSIDERED GRAND MARAIS COULEE
CHANNEL IMPROVEMENTS

FIGURE 11

has a bank-full capacity of only about 3,000 cfs; numerous small bridge and culvert openings and natural channel constrictions severely restrict flow. Thus, the considered diversion would cause major flooding along the coulee in its existing state, causing serious damages to adjacent farmlands, roads, and bridges. To pass the considered 11,500 cfs plus the coulee's own 100-year runoff, the coulee's channel would have to be widened to a 200-foot bottom width, several meanders would be cut off, and 1 railroad and 12 highway bridges would have to be replaced.

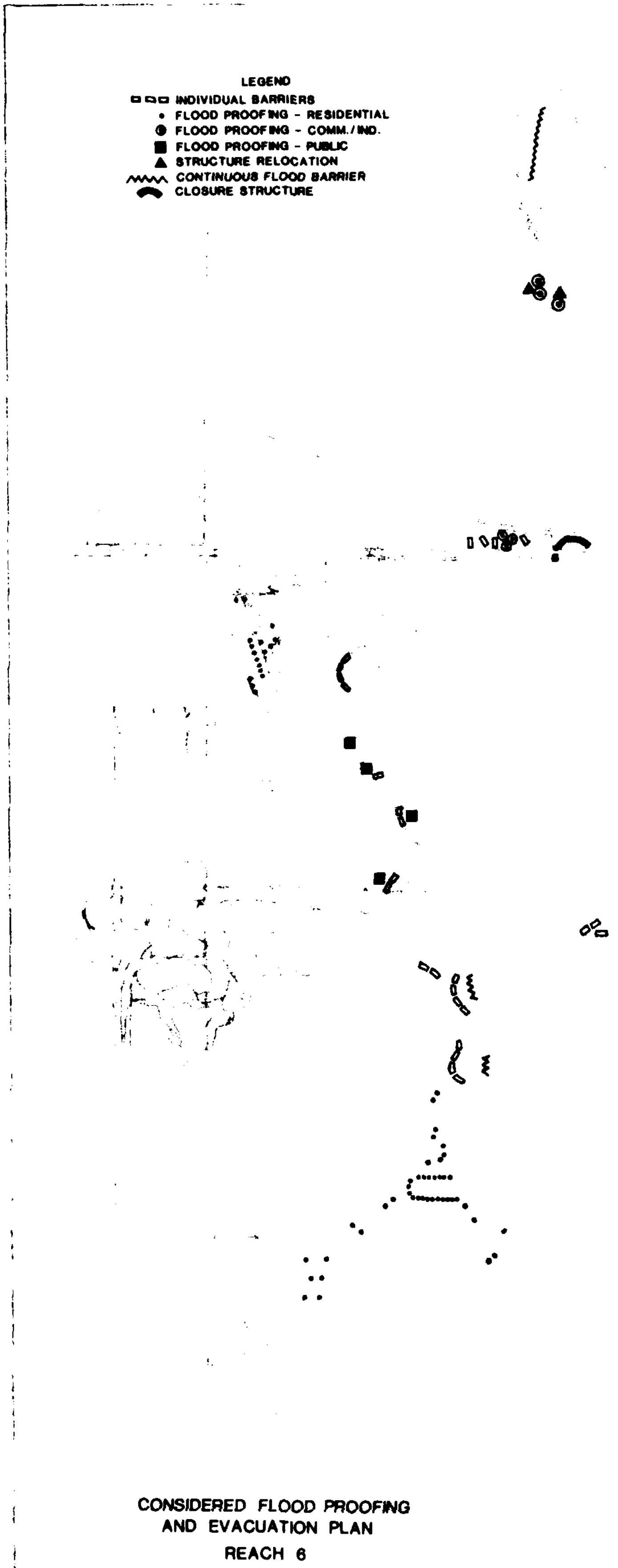
- Combine evacuation and flood proofing in Reaches 1 and 6 - Criteria were established for flood proofing: a structure should not be more than 100 feet within the 100-year flood outline and/or should not have a first-floor elevation more than 2 feet below the 100-year flood elevation. Structures not meeting these criteria would be evacuated - either relocated to a flood-free site or razed depending on structure type and condition. Types of flood proofing measures considered included low berms or concrete walls to protect walkout basements or small clusters of structures, permanent or temporary bulkheads on low-level door or window openings, floor drain standpipes and/or check valves, relocation of utilities and other equipment to higher floors, reinforcement and waterproofing of masonry walls, raising the structure on earth fill, and closures on selected culverts to prevent backwater flooding. In Reach 1, 256 residences and 2 public structures could be flood proofed (figure 12). In Reach 6, approximately 358 residences, 15 commercial/industrial structures, and 11 public buildings are located in the English Coulee's 100-year floodplain. The Reach 6 alternative that was considered assumes the city's recently completed project to protect the Westward Acres portion of the city (located just south and east of the DeMers Avenue-Columbia Road intersection) protects to the 100-year level. This project involved raising South 30th Street and installing flap gates on two storm sewers; in addition, during floods, the city will need a temporary sandbag closure across DeMers Avenue. The flood proofing and evacuation alternative was examined at the 25-, 50-, and 100-year levels of protection. At the 100-year level, 132 structures would be involved (figure 13).



CONSIDERED FLOOD PROOFING AND EVACUATION PLAN

REACH 1

FIGURE 12



CONSIDERED FLOOD PROOFING
AND EVACUATION PLAN
REACH 6

FIGURE 13

- Construct closure structure/pumping station at the Belmont Road crossing of Belmont Coulee - The plan that was originally developed by the North Dakota State Water Commission would protect to the 100-year level. The closure structure would tie into the existing Belmont Road. A flap-gated culvert would pass coulee flows to the Red River under non-flood conditions. When the Red River was flooding, the culvert would be sealed and pumps would be used to discharge runoff from the coulee's drainage area.

- Raise Belmont Road to prevent overtopping by Red River floodwaters - The road would be raised between 13th and 17th Avenues South (a total length of about 1,160 feet). The maximum practical raise would protect to about the 50-year level.

- Flood barriers along English Coulee - This alternative was dismissed as impracticable and economically unjustifiable by the consultant without resorting to a formal formulation and evaluation. Room between many structures and the coulee for Corps-standard levees is insufficient and the extent of either levees or floodwalls that would be needed would be too costly to justify given the relatively low density of damageable properties that would be protected. Thus, this alternative was dropped from further consideration.

Alternative Evaluations and Impact Assessments

Construction costs for these alternatives included a 25-percent factor for contingencies and 15 percent to cover engineering, design, supervision, and administration. First costs were amortized using an interest rate of 6 7/8 percent over a 100-year economic life and August 1979 price levels. Annual costs also included operation and maintenance expenses. Annual benefits were computed from the damage-elevation, elevation-discharge, discharge-frequency, and frequency-damage relationships developed for the stage 2 studies with results updated to August 1979 price levels. In accordance with floodplain regulations, it was assumed that the number of flood-prone structures would not increase over the 50-year period of analysis. However, increases in damages resulting primarily from the growing value of residential contents were included. Table 4 summarizes the first costs, annual costs, annual benefits, and benefit-cost ratios for the various alternatives and options that were completely evaluated.

Table 4 - Summary of results of economic analyses

Item	Lincoln Park flood barrier raise	Riverside Park flood barrier: Levee/floodwall	Riverside Park flood barrier: All levee	English Coulee closure structure	Grand Marais coulee diversion	Evacuation and flood proofing Reach 1	Evacuation and flood proofing Reach 6	Belmont Coulee closure structure	Belmont Road raise
25-year protection:									
Total first cost	NA	NA	NA	$1,068,000	NA	$20,000	$117,000	NA	NA
Total annual cost				74,500		1,700	8,400		
Average annual benefits				26,000		12,000	47,000		
Benefit-cost ratio				0.4 (2)		7.1	5.6		
50-year protection:	(1)								
Total first cost	$387,000	$2,595,000	$3,597,000	$1,187,000	$28,798,000	$431,[illegible]00	$463,[illegible]	NA	$284,000
Total annual cost	27,000	192,900	262,100	82,600	1,989,000	31,800	32,[illegible]		19,800
Average annual benefits	36,900	59,000	59,000	49,000	344,000	31,000	83,000		10,000
Benefit-cost ratio	1.4 (2)	0.3 (2)	0.2 (2)	0.6 (2)	0.2 (2)	0.97	2.5		0.5 (2)
100-year protection:									
Total first cost	NA	$3,643,000	$4,467,000	$1,351,000	$36,314,000	$2.596.000	$1,173,000	$692,000	NA
Total annual cost		269,800	327,500	93,900	2,503,000	182,900	81,800	50,000	
Average annual benefits		88,000	88,000	86,000	421,000	58,000	125,000	25,000	
Benefit-cost ratio		0.3	0.3	0.92	0.2	0.3	1.5	0.5	

(1) Maximum level of protection with 3 feet of freeboard is 47 years.

(2) Current policy precludes Corps participation in a permanent urban structural flood control project with this degree of protection.

The only structural measure that appears economically justifiable is the Lincoln Park flood barrier raise. However, current policy does not permit Corps involvement in a permanent structural project providing such a low degree of protection for an urban area. The potential for catastrophe, including possible loss of life, is considered too high. If a flood exceeds the level of protection, the sudden influx of floodwaters could cause more damages than the slow rise of floodwaters under natural conditions. Furthermore, the physical barrier provided by a levee can give a false sense of security and, therefore, encourage residents to remain in their homes during a flood threat thereby increasing the risk of injury or loss of life. Consequently, this particular measure is not implementable insofar as Corps participation is concerned.

The English Coulee closure alternative is marginally infeasible with a benefit-cost ratio of 0.92 at the 100-year level of protection. Furthermore, preliminary surveys of adjacent high ground show the maximum freeboard at this level of protection would be 2.5 feet instead of the desired 3 feet. However, this alternative is recommended for further investigation because the quality of available hydraulic, hydrologic, and flood damage data for the coulee is relatively poor; more detailed studies could significantly affect economic feasibility.

The two nonstructural measures - flood proofing and evacuation in Reaches 1 and 6 - also appear to warrant further consideration. In Reach 1, the benefit-cost ratio exceeds 1.0 below the 50-year level of protection. In Reach 6, the benefit-cost ratio is well above 1.0 up to and beyond the 100-year level of protection, although the economic optimum appears to be at a lower level of protection.

Adverse environmental and social impacts of evacuation and flood proofing in Reaches 1 and 6 are minor. Relatively few structures would be evacuated; hence, social disruption would be insignificant. It also follows that the costs and environmental consequences of a redevelopment area for relocated homes and businesses would be minimal. Relatively minor, short-term environmental degradation would be incurred during

construction as a result of dust and turbid runoff, but these impacts could be controlled through standard construction practices. Providing flood protection would provide significant social benefits that would far outweigh the few negative aspects.

The impacts from the English Coulee closure structure/pumping station would be relatively minor - no relocations would be needed and the environment at the facility's site is already disturbed. Adverse environmental and social impacts of the other alternatives are generally significantly greater. The flood barrier alternatives involve removal of 2 to 22 homes which, in the latter case, represents a significant social minus. The environmental impacts would not be major because most of the lands required are already used for emergency flood works or would be evacuated homesites.

The Grand Marais Coulee diversion scheme would result in major deleterious environmental consequences. The coulee is a rich source of wildlife; a great change in flood frequency and magnitude and/or a channel widening and straightening project would probably destroy a large share of the coulee's natural habitat.

Recommendations

The following recommendations are directed at two audiences: local interests - regarding what they might do with a reasonable investment to significantly reduce their flood susceptibility - and Corps higher authority - regarding what direction future studies might take to determine the eventual Federal role in permanent flood damage reduction measures. The following recommendations are abbreviated versions of those listed in the urban study's Flood Control Appendix. The latter includes additional explanatory material for the reader interested in further details.

Recommendations for nonstructural improvements by local interests include:

- The city should enforce existing floodplain management ordinances.
- The city should annually notify residents in the 100-year floodplain of their flood potential.

- The city should maintain its eligibility and encourage citizen participation in the Federal flood insurance program.

- Property owners should flood proof their properties where feasible.

- The city should consider acquiring and removing flood-prone structures from the 100-year floodplain as they become available and convert the evacuated areas to recreational or open-space uses.

- The city should annually review and update the flood fight manual.

Grand Forks should consider the following structural measures. These measures, though not cost effective when the Corps' extremely high design standards are used, might be built by the city at a significant cost savings with some modifications to the Corps' design. For example, interior drainage can be handled much cheaper by temporary, portable pumps rather than by a permanent pumping station.

- The city should consider constructing a closure structure and pumping facilities at the Belmont Road crossing of Belmont Coulee.

- The city should consider raising Stanford Road between U.S. Highway 2 and 13th Avenue North and installing operable culvert closures and interior drainage pumping facilities to prevent flooding by English Coulee backwater along the swale behind Stanford Road.

- The city should consider raising Belmont Road between 13th and 17th Avenues South, relocating a sanitary sewage lift station, and providing interior drainage pumping facilities.

- The city should consider relocating the frequently flooded Lincoln Park recreation building.

The following recommendations pertain to additional studies considered necessary by the urban study's staff to establish the feasibility of Federal involvement in permanent flood protection:

- The following alternatives should be studied in greater detail:

    - Reach 1 - Combined flood proofing and evacuation.
    - Reach 6 - English Coulee closure.
    - Reach 6 - Combined flood proofing and evacuation.

- The feasibility of increasing the flow capacity of the Burlington Northern railroad bridge across English Coulee near DeMers Avenue should be analyzed.

- The above recommended studies should be transferred to the Corps small flood control project continuing authority (Section 205 of the 1948 Flood Control Act, as amended).[1]

- During further studies of English Coulee, the Corps should coordinate closely with the SCS.[2]

- Specific topics that need further attention during the recommended Section 205 studies include:

    - Topographic mapping for use in hydraulic and damage/benefit analyses.
    - Flood damage and benefit analyses, particularly in the English Coulee area upstream of DeMers Avenue.

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(1) The Section 205 continuing authority offers a quicker path to more detailed studies and potential construction than the normal feasibility study which could typically involve 8 to 14 years for Washington-level review, preconstruction planning, and congressional authorization and funding. During this period, the rising Federal discount rate can erode the economic feasibility of promising measures.

(2) The dry dam and diversion ditches being considered for the coulee's upper watershed by the SCS would greatly reduce flows entering the city, thereby significantly affecting the feasibility of urban flood protection measures being considered by the Corps.

- Hydraulics and hydrology.[1]
- Environmental/social impact analyses.[2]

Flood Emergency Plan of Action

The need for a flood emergency plan of action for Grand Forks was clear. The federally constructed Lincoln Park levee/floodwall protects to a relatively low level. Emergency levees provide an unreliable degree of protection to some neighborhoods. These levees experience subsidence problems and do not meet accepted design or construction standards for permanent projects.

The urban study has shown that Federal participation in permanent flood control improvements may be justifiable, at best, only in one or two areas of the city. The city and its residents could take the initiative and undertake effective measures at a modest cost - for example, raising selected roads as was done to 30th Street South by the city and flood proofing by individual homeowners and businessmen. However, much of the city will continue to be subject to recurring flood threats and will continue to rely on emergency flood fighting.

The Corps, its consulting engineers for flood-related investigations in the urban study area, and the Flood Emergency Plan of Action Task Force appointed by the Grand Forks mayor jointly developed a flood fight manual entitled Flood Emergency Plan for Grand Forks, North Dakota. This manual (published as a separate urban study document) is, in effect, a nonstructural measure that complements structural measures, both permanent and emergency.

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(1) As mentioned earlier, the frequency-discharge relationship of the Red River was recently revised. The impact on the economic and engineering feasibility of the measures recommended for further study must be determined. English Coulee has no gage records; hydraulic and hydrologic data from various sources differ to the extent that further study is warranted to reconcile the discrepancies.

(2) An environmental impact statement or finding of no significant impact will be needed if an alternative is recommended for construction. Work accomplished under the urban study will be used in the Section 205 studies; a survey was conducted to determine the public's attitudes toward floods and flood protection; a cultural resources literature search and records review was conducted.

The manual covers the following:

- Coordination between local, State, and Federal agencies involved in the flood fight or postflood rehabilitation and relief efforts.

- The city's flood fight organization and emergency operation center.

- The flood threat - water surface profiles, flooded area outlines.

- Existing flood control facilities - permanent and emergency flood barriers.

- Preflood preparations - instruction, inspections, maintenance, inventories, stockpiling.

- Flood fighting - warning levels, mobilization of city resources and volunteers, raising of flood barriers, interior drainage pumping, dike patrols, citizen self-help plans.

- Contingency plans for emergencies - evacuation plans and routes.

- Postflood activities - cleanup, damage, and flood fight cost estimates for aid requests.

The manual should be updated annually by the city to reflect current personnel, equipment, and facilities. If the Corps and/or the city provides permanent flood control measures at a later date, the manual should be revised.

URBAN DRAINAGE STUDIES

Urban drainage studies were undertaken after city officials requested assistance in developing an urban drainage master plan to help combat adverse impacts on runoff from continued urban development. As development consumes natural infiltration and storage areas, runoff peak rate and

volume increase unless compensatory measures are taken. Increased runoff would put an added burden on existing and future drainage systems. During severe conditions, as during the 1979 flood, large areas are susceptible to flooding from overland sheet flow which exceeds the drainage network's capacity.

The time frame for the urban drainage studies was the period 1980-2030. The study area was the predominately agricultural lands outside the sewered portion of the city and within the city's land use zoning jurisdiction which extends 2 miles beyond the city limits. Also, the study area was extended an additional mile south in the rapidly developing area between the Red River and Interstate 29 (figure 14).

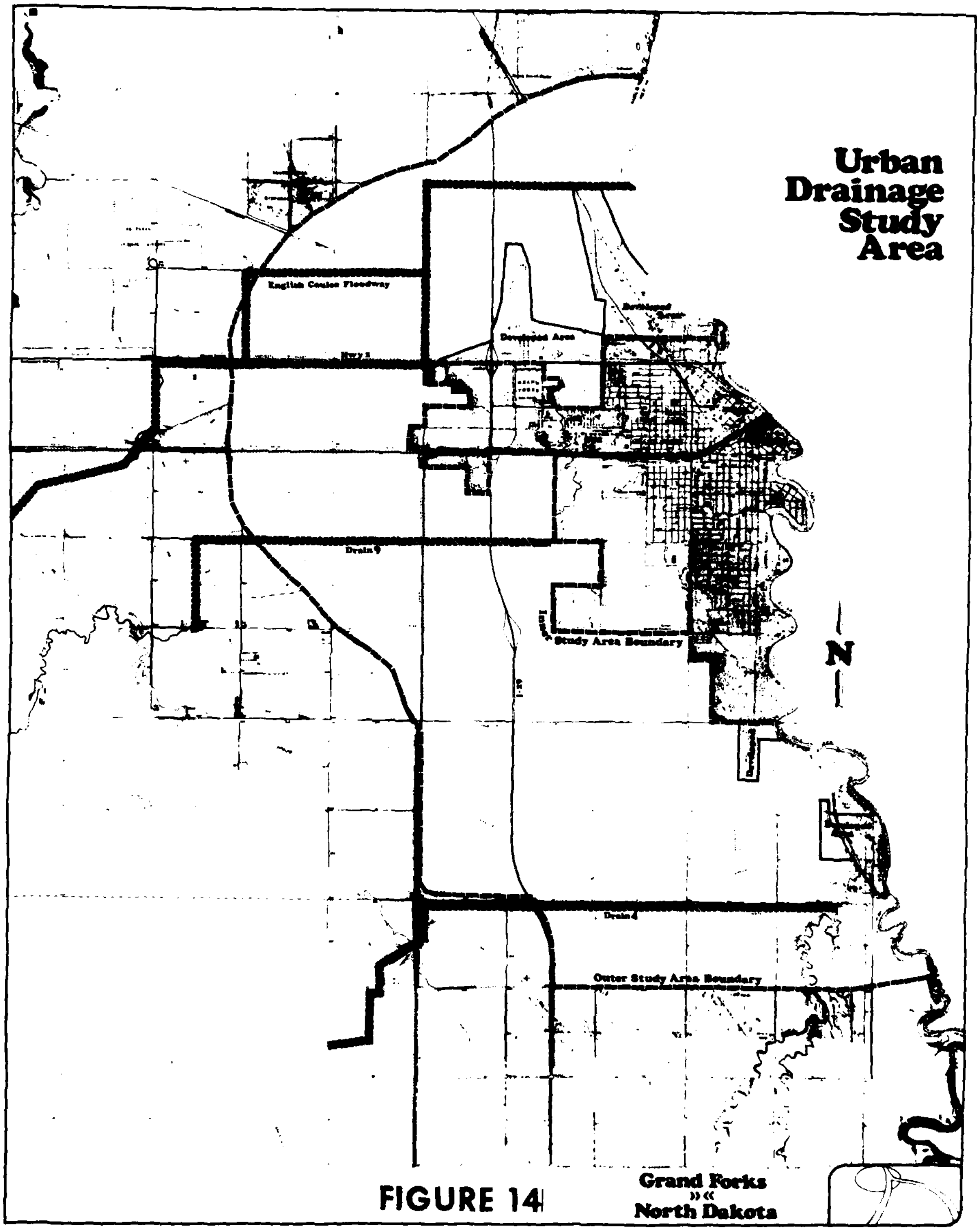

Urban
Drainage
Study
Area
English Coulee Floodway
Hwy 2
Drain 9
Study Area Boundary
N
Drain 4
Outer Study Area Boundary
Grand Forks
North Dakota

FIGURE 14

The stage 2 study developed eight conceptual drainage plans ~~comprising~~ combinations of alternative runoff storage facilities, conveyance means and routes, and design capacities. Economic, social, and environmental consequences were examined. It was concluded that ditches would be less costly than conduits and would be more adaptable to future changes, but would have more adverse environmental and social impacts. Small temporary storage areas, such as in swales, streets, or ponds, also showed promise. It was recommended that stage 3 studies quantify urban runoff and the existing drainage system capacity. If deficiencies were found, possible improvements should be studied incorporating a combination of local storage and conduit interceptors to reduce costs, retain gravity flow, and attenuate runoff peaks.

The stage 3 studies were based on a number of assumptions regarding land use and drainage developments over the 1980-2030 time frame. The study area and surrounding lands that drain into the study area were divided into 65 subwatersheds, each uniquely defined in terms of location, total area, impervious area, and drainage characteristics.

Two fundamental assumptions regarding hydraulics and hydrology were made:

- Natural drainage patterns in undeveloped areas outside, but tributary to the study area, would not be altered by future development.

- With two exceptions, the capacities of existing channels, culverts, and bridges at the boundaries of the study area would not change.

The exceptions referred to were changes primarily to direct flow away from the English Coulee drainage within the study area and thereby reduce the urban flooding potential!

- Completion of a planned diversion structure by the Grand Forks County Water Management and Control Board. This structure would divert part of the runoff from the upper portion of the coulee watershed into the English Coulee floodway to Legal Drain 23, Legal Drain 18, and the Red River (see figure 14).

- Construction of a 3 1/4-mile east-west open ditch along 47th Avenue South to divert water south of 32d Avenue South away from English Coulee and directly to the Red River.

Alternative drainage plans were based primarily on conduits with and without storage areas in accordance with the stage 2 recommendations. Design criteria included:

- Lateral storm sewers sized to handle runoff from a 10-year rainfall with no street flooding.

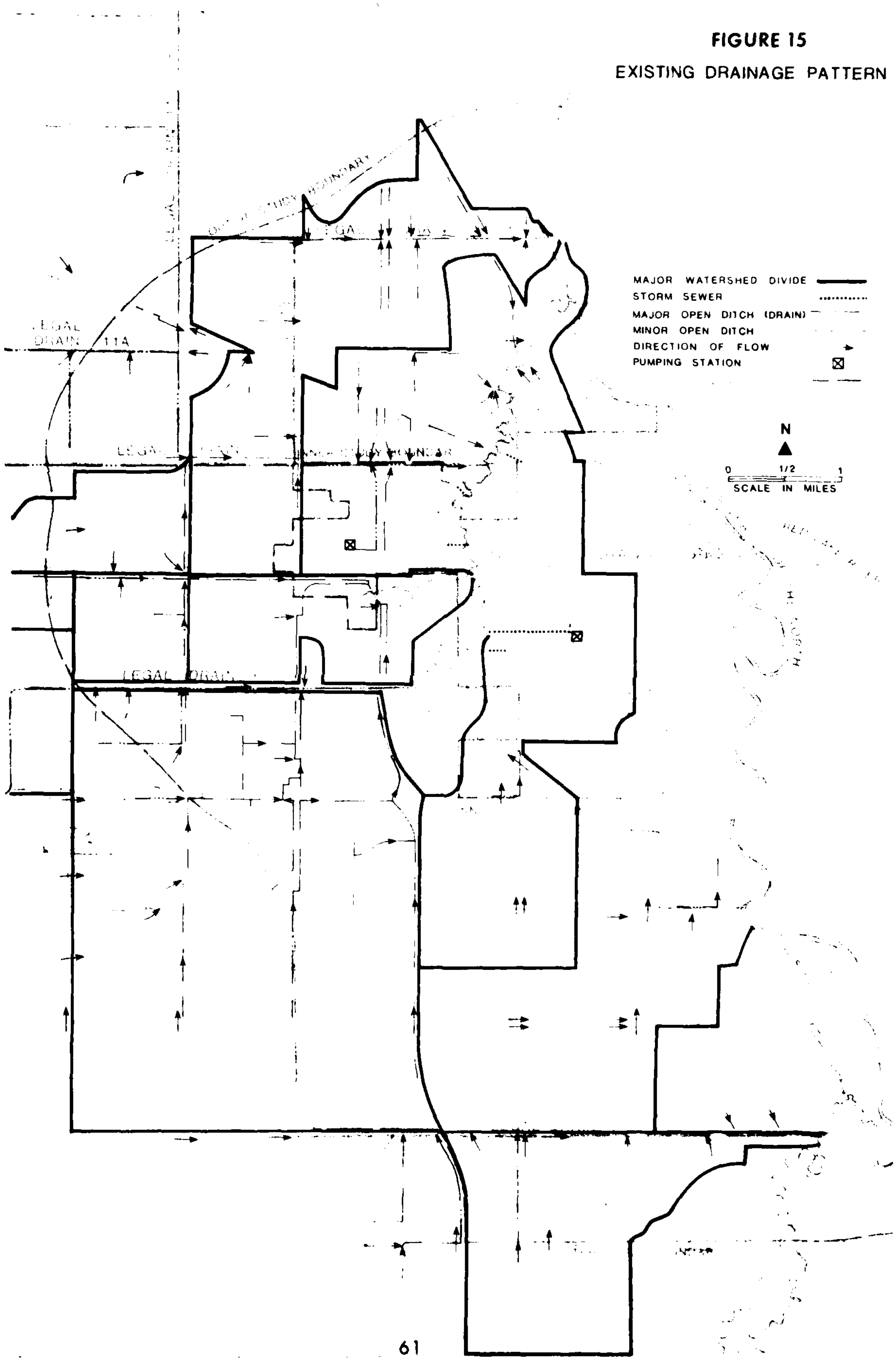
- Storage areas, major trunk sewers, culverts, and legal drains sized to handle runoff from a 100-year rainfall.

Runoff hydrographs for watersheds outside the study area were developed using the SCS hydrologic model TR-20 in conjunction with the SCS dimensionless Type I rainfall distribution hyetograph. Runoff from both rainfall and snowmelt was considered in selecting the critical storms for waterways affecting the study area. Runoff discharges and volumes within the study area were determined using the Barr Hydrograph Method (a synthetic hydrograph method for urban drainage analyses); discharges were checked with the Rational Method.

Two drainage system alternatives were developed. Both options maximize use of existing drainage systems and minimize use of open ditches. Also, as described above, they incorporate changes in the existing drainage pattern (figure 15) to reduce the quantity of runoff reaching the English Coulee main channel.

FIGURE 15

EXISTING DRAINAGE PATTERN



Option A (figure 16) differs from Option B (figure 17) in that the latter provides for the development of runoff ponding areas whereas Option A assumes direct runoff into storm sewers and ditches and thence to English Coulee and the Red River. Option A also requires improvement of existing culverts, bridges, and channels within the study area, particularly along the English Coulee main channel.

Option B's temporary runoff storage attenuates peak discharges and, therefore, permits this option to get by with smaller sewers than needed for Option A. The storage areas for Option B are sized to keep runoff peaks with 2030 development at current (1978) rates. Table 5 shows the runoff rates and volumes resulting from a 100-year storm both with existing land uses and under assumed 2030 conditions with Options A and B.

Figure 17 shows a conceptual view of Option B; the actual size, shape, and location of temporary storage areas would be determined by detailed case-by-case studies as implementation becomes necessary. Individual storage areas could be combined as long as the total volume of the combined site equaled the sum of the individual areas. Also, the type of storage facility is flexible:

- Park areas could be developed in conjunction with the temporary runoff storage function. Existing parks could be landscaped to provide the necessary storage.

- If parkland area is not available, storage could be provided by dual-purpose facilities, such as depressed parking lots, flat building roofs, ditches with controlled outlets, etc.

Construction of storage areas could be deferred until development took place, thereby spreading out the economic impact. The developers themselves, who would be responsible for providing the storage areas, would be subject to smaller assessments from the city because of the smaller sewers needed with Option B.

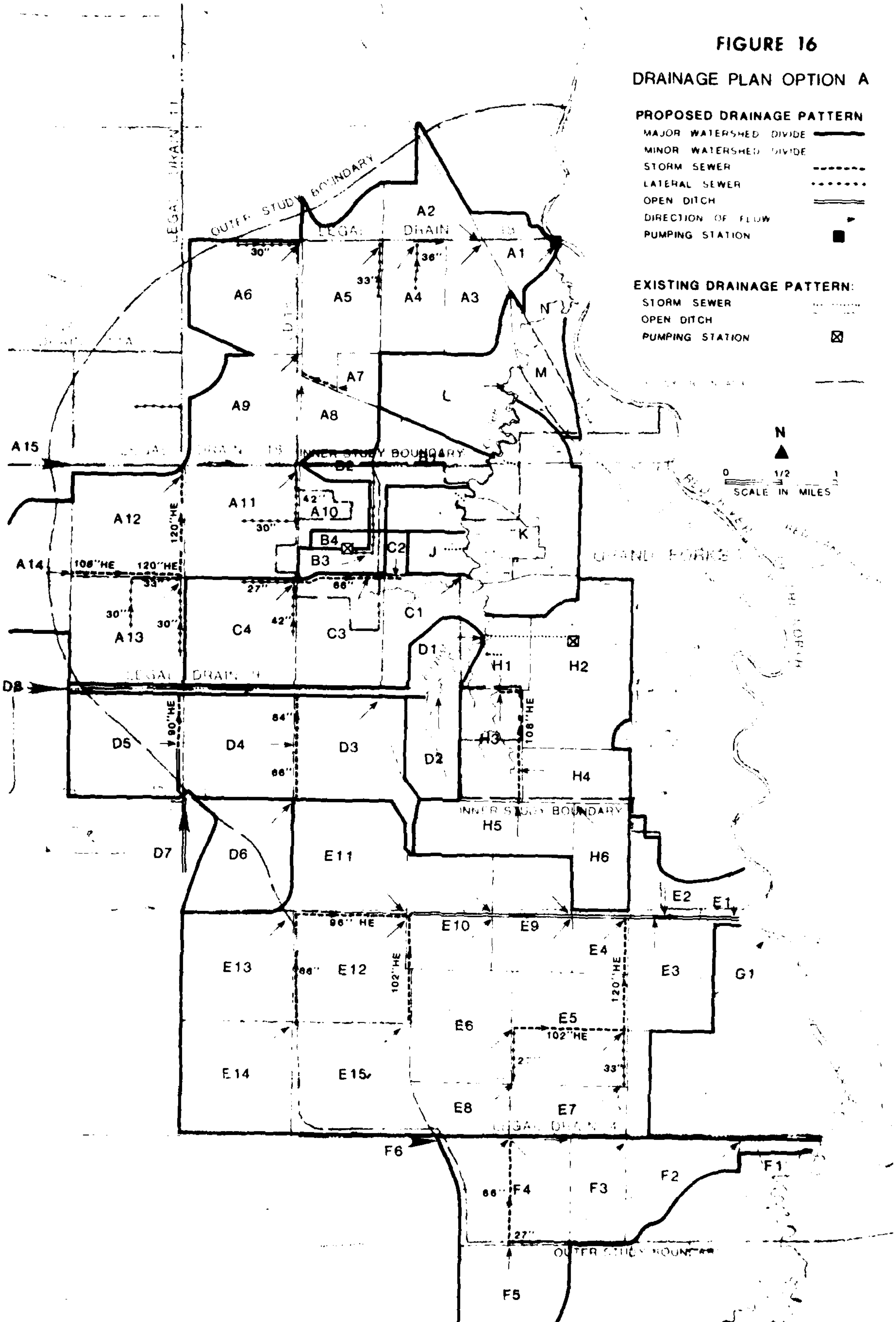


FIGURE 16
DRAINAGE PLAN OPTION A
PROPOSED DRAINAGE PATTERN
MAJOR WATERSHED DIVIDE
MINOR WATERSHED DIVIDE
STORM SEWER
LATERAL SEWER
OPEN DITCH
DIRECTION OF FLOW
PUMPING STATION
EXISTING DRAINAGE PATTERN:
STORM SEWER
OPEN DITCH
PUMPING STATION
N
SCALE IN MILES
OUTER STUDY BOUNDARY
INNER STUDY BOUNDARY
LEGAL DRAIN
GRAND FORKS

FIGURE 17

DRAINAGE PLAN OPTION B

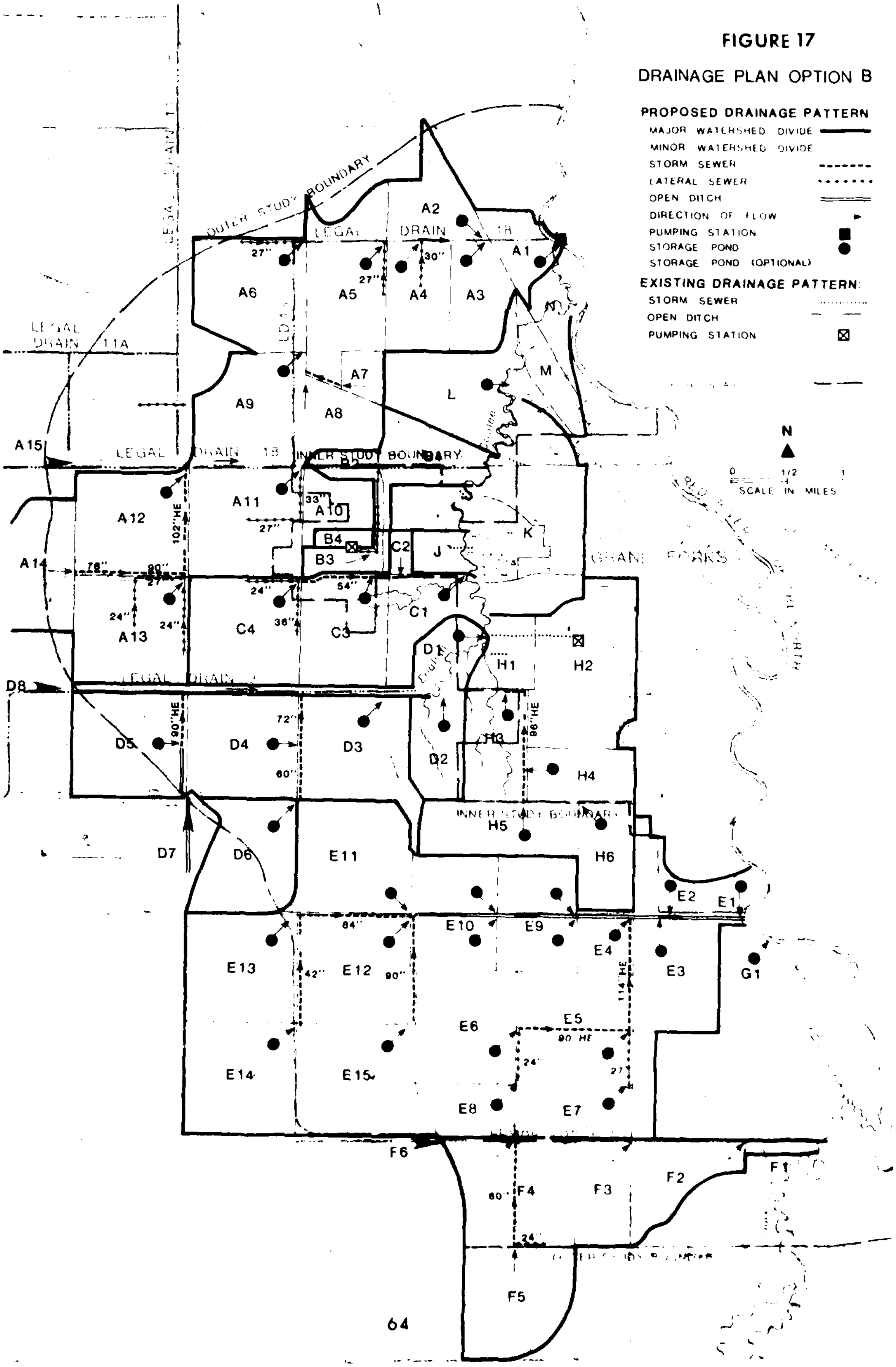


Table 5 - Comparison of discharges and corresponding runoff volumes - proposed drainage pattern, 100-year frequency storm

Area Name	EXISTING LAND USE (1978)		FUTURE LAND USE (2030)				
			OPTION A		OPTION B		
	Qmax (cfs)	Runoff Volume (A-F)	Qmax (cfs)	Runoff Volume (A-F)	Qmax (cfs)	Runoff Volume (A-F)	Storage Volume (A-F)
A1	140	20	165	24	140	24	4
A2	200	36	265	51	200	51	15
A3	185	34	230	43	185	43	9
A4	145	26	180	33	145	33	7
A5	165	28	195	46	165	46	18
A6	230	52	265	60	230	60	8
A7	40	9	45	11	40	11	2
A8	85	22	145	37	85	37	15
A9	265	50	310	59	265	59	9
A10	80	21	105	27	80	27	6
A11	165	47	195	57	165	57	10
A12	210	43	250	53	210	53	10
A13	175	47	210	57	175	57	10
A14	125	37	155	46	125	46	9
B1	280	46	320	51	280	51	5
B2	20	5	20	8	20	8	3
B3	40	11	65	18	40	18	7
B4	30	5	40	6	30	6	1
C1	170	26	190	29	170	29	3
C2	20	4	40	8	20	8	4
C3	205	44	345	76	205	76	32
C4	135	40	160	49	135	49	9
D1	115	18	130	21	115	21	3
D2	190	27	315	47	190	47	20
D3	185	46	220	56	185	56	10
D4	165	45	195	54	165	54	9
D5	155	42	180	50	155	50	8
D6	115	32	140	39	115	39	7
E1	60	8	65	10	60	10	2
E2	75	17	90	20	75	20	3
E3	140	40	165	48	140	48	8
E4	40	11	50	13	40	13	2
E5	115	39	140	47	115	47	8
E6	115	38	140	46	115	46	8
E7	40	13	45	16	40	16	3
E8	40	12	45	14	40	14	2
E9	90	28	115	36	90	36	8
E10	85	28	110	35	85	35	7
E11	150	45	180	54	150	54	9
E12	135	41	165	50	135	50	9
E13	85	30	100	37	85	37	7
E14	70	27	90	33	70	33	6
E15	120	37	145	45	120	45	8
F1	50	5	60	6	50	6	1
F2	75	22	90	26	75	26	4
F3	100	26	125	32	100	32	6
F4	135	39	160	47	135	47	8
F5	95	30	115	37	95	37	7
G1	1,245	149	1,340	167	1,245	167	18
H1	145	15	180	19	145	19	4
H2	440	93	450	95	440	95	2
H3	120	34	160	46	120	46	12
H4	-	-	-	-	-	-	-
H5	80	26	105	35	80	35	9
H6	60	20	90	30	60	30	10
I	170	28	190	32	170	32	4
J	190	25	195	26	190	26	1
K	570	105	635	120	570	120	12
L	530	66	855	92	530	92	26
M	105	26	110	29	105	29	3
N	120	19	135	21	120	21	2

The urban drainage report also recommended that the outlets of Legal Drain 18 and the English Coulee main channel be combined and that a closure structure be constructed to prevent backwater from flood stages on the Red River from interfering with drainage down the legal drain and coulee. A pumping station would pump the combined runoff i o the Red River during high river stages. Under Option A, a pumping capacity of 2,000 cfs under a 5-foot head would be needed. Under Option B, the attenuated peak flows would reduce the pumping requirements to 1,500 cfs. During low stages on the Red River, the closure structure would be opened to permit gravity flow from the legal drain and coulee.

The closure/pumping facility is expensive, and the city might desire phased construction. Immediate construction is not necessary; areas that might be flooded because of backwater effects are not developed intensively yet; however, these areas are zoned commercial and industrial, and development potential could be adversely affected by the threat of flooding. One alternative might be to construct a facility near the mouth of English Coulee with pumps sized just for coulee runoff; at a later date, the mouth of Legal Drain 18 could be plugged, a ditch dug to divert the outflow from the legal drain int the coulee, and the pump capacity increased to handle the extra runoff. Note that one of the Grand Forks flood control alternatives considered consists of a closure structure/pumping station near the mouth of the coulee.

Table 6 presents estimated costs for the two options. These estimates exclude the city's administrative costs for the urban drainage program and developers' costs under Option B to provide the storage areas. Option B obviously is more cost effective from the city's viewpoint, with total first costs of $26 million compared to nearly $35 million for Option A, and average annual costs of less than $1.9 million compared to $2.5 million.

The most significant adverse environmental impacts from the urban drainage system would occur during construction: soil erosion, turbidity in receiving waters, possible loss of trees, etc. Option B, because of its

Table 6 - Preliminary cost estimates

OPTION A

ITEM	Quantity	Unit	Unit Cost	Item Cost	Total Cost	Annual Cost
Open Ditch	3¼	mi	221	718		
Open Ditch Outlet	1	ea	12	12		
Total Cost of 47th Avenue Open Ditch					730	
RCP 120" HE	2½	mi	1,963	4,908		
RCP 108" HE	1½	mi	1,752	2,628		
RCP 102" HE	2	mi	1,620	3,240		
RCP 96" HE	1	mi	1,488	1,488		
RCP 90" HE	½	mi	1,382	691		
RCP 84"	½	mi	1,039	520		
RCP 66"	3	mi	770	2,888		
RCP 42"	1	mi	495	495		
RCP 36"	½	mi	402	201		
RCP 33"	1½	mi	339	508		
RCP 30"	2	mi	270	540		
RCP 27"	1¼	mi	207	259		
Total Cost of Storm Sewers (18 miles)					18,366	
Pump Station	2,000	cfs	2.6	5,200		
Pond	5	AF	4.0	20		
Total Cost of Special Outlet Structure					5,220	
Contingencies	20%				6,890	
Engineering	10%				3,445	
TOTAL FIRST COST OF OPTION A					34,651	
Annual Capital Recovery Cost at 6 7/8 %, 50 years						2,471
Annual Operation & Maintenance						
Open Ditch	3¼	mi	0.6	2		
S. Sewers	18	mi	0.4	7		
Sp. Outlet	1	ea	20	20		
Total Annual Operation & Maintenance						29
AVERAGE ANNUAL COST						2,500

OPTION B

ITEM	Quantity	Unit	Unit Cost	Item Cost	Total Cost	Annual Cost
Open Ditch	3¼	mi	196	637		
Open Ditch Outlet	1	ea	10	10		
Total Cost of 47th Avenue Open Ditch					647	
RCP 114" HE	1	mi	1,858	1,858		
RCP 102" HE	1	mi	1,620	1,620		
RCP 96" HE	1	mi	1,488	1,488		
RCP 90" HE	1½	mi	1,382	2,073		
RCP 84" HE	1	mi	1,277	1,277		
RCP 90"	1½	mi	1,145	1,718		
RCP 78"	½	mi	949	474		
RCP 72"	½	mi	860	430		
RCP 60"	½	mi	680	340		
RCP 54"	1¼	mi	585	731		
RCP 42"	1	mi	495	495		
RCP 36"	½	mi	402	201		
RCP 33"	½	mi	339	170		
RCP 30"	½	mi	270	135		
RCP 27"	2¼	mi	207	466		
RCP 24"	2⅛	mi	144	308		
Total Cost of Storm Sewer					13,784	
Pump Station	1,500	cfs	2.6	3,900		
Pond	4	AF	4.0	16		
Total Cost of Special Outlet Structure					3,916	
Contingencies	20%				5,186	
Engineering	10%				2,593	
TOTAL FIRST COST OF OPTION B					26,126	
Annual Capital Recovery Cost at 6 7/8 %, 50 years						1,863
Annual Operation & Maintenance						
Open Ditch	3¼	mi	0.6	2		
S. Sewer	18	mi	0.4	7		
Sp. Outlet	1	ea	15	15		
Total Annual Operation & Maintenance						24
AVERAGE ANNUAL COST						1,887

*Cost unit is $1,000

storage areas, probably will cause greater construction impacts than Option A. Conversely, Option B has the potential for much greater long-term environmental enhancement if the storage areas are developed in association with park and recreation areas. The urban drainage master plan (which is included in the urban study's Flood Control Appendix) addresses the possibility of pollutants and nutrients collecting in permanent ponds that might be part of Option B's system of storage areas. Various solutions, including source control or inflow treatments, are available. Because both options maximize use of existing drainage facilities, the net adverse impact on the environment would be minimized.

Social and cultural impacts, except for temporary adverse effects during construction, are overwhelmingly positive. Control of runoff, hence reduction of flooding problems and their toll of misery, is commendable. But Option B offers even more - the possibility of incorporating recreational facilities and aesthetic improvements that could reduce the predicted future shortage of such opportunities. Option B has another advantage - it gives the city flexibility in land use zoning and implementation because peak runoffs from each subwatershed are fixed; the eventual development can be selected on the basis of criteria other than the effect on runoff as long as the developer provides storage areas to keep the runoff rate from changing.

Because of its greater cost effectiveness, flexibility, and recreational and aesthetic potential, Option B is recommended for implementation. This plan requires that the city pass a drainage ordinance which, in turn may require the city to form a watershed district to obtain legal authority to initiate drainage changes, enforce the ordinance, and assess costs in proportion to contributions to drainage problems and benefits received from the project. Alternatively, the Grand Forks County Water Management Control Board could assume the responsibilities and powers of a watershed district.

The SCS is developing a plan[1] for the English Coulee watershed that could have a major impact on the Grand Forks urban drainage picture. The plan (parts of which are shown on figure 18) includes:

- A 5-mile-long dry dam (about 4 miles upstream from the diversion structure being built by the Water Management Control Board) would control a drainage area of about 57 square miles (about half the total English Coulee watershed) and would create a 2 1/2- to 3-square mile pool during a 100-year rainfall. The dam's discharge in this event would be about 450 to 600 cfs.

- Outflow from the dam would combine with local runoff below the dam. The diversion structure would split the flow - part would be directed northward into the English Coulee floodway to Legal Drains 23 and 18; the rest would continue down the coulee to Legal Drain 9, then straight north via 1 mile of Legal Drain 9[2] and 2 miles of new ditch to Legal Drain 18 where the flow from the floodway would be rejoined. The total flow would then be routed north and east via a new crossing under Highway 2 to Legal Drain 11, thence north and east to the Red River via 1 mile of new ditch and Legal Drain 18. This plan would require increased crossing capacities under the Burlington Northern railroad right-of-way and Interstate 29.

- Another new diversion ditch is also under consideration. This ditch would run south 3 miles from near English Coulee and then east to Legal Drain 4, which carries flow to Cole Creek just upstream of its confluence with the Red River.

- Excess earth from excavating new ditches would be used to construct dikes on the cityward side of the ditches to keep water from flowing overland toward Grand Forks if the ditches' design capacities are exceeded.

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(1) At the time the urban drainage master plan was being written, many details of the SCS plans were not firmly established.

(2) A plug would prevent flow into the eastward leg of Legal Drain 9 that enters the city.

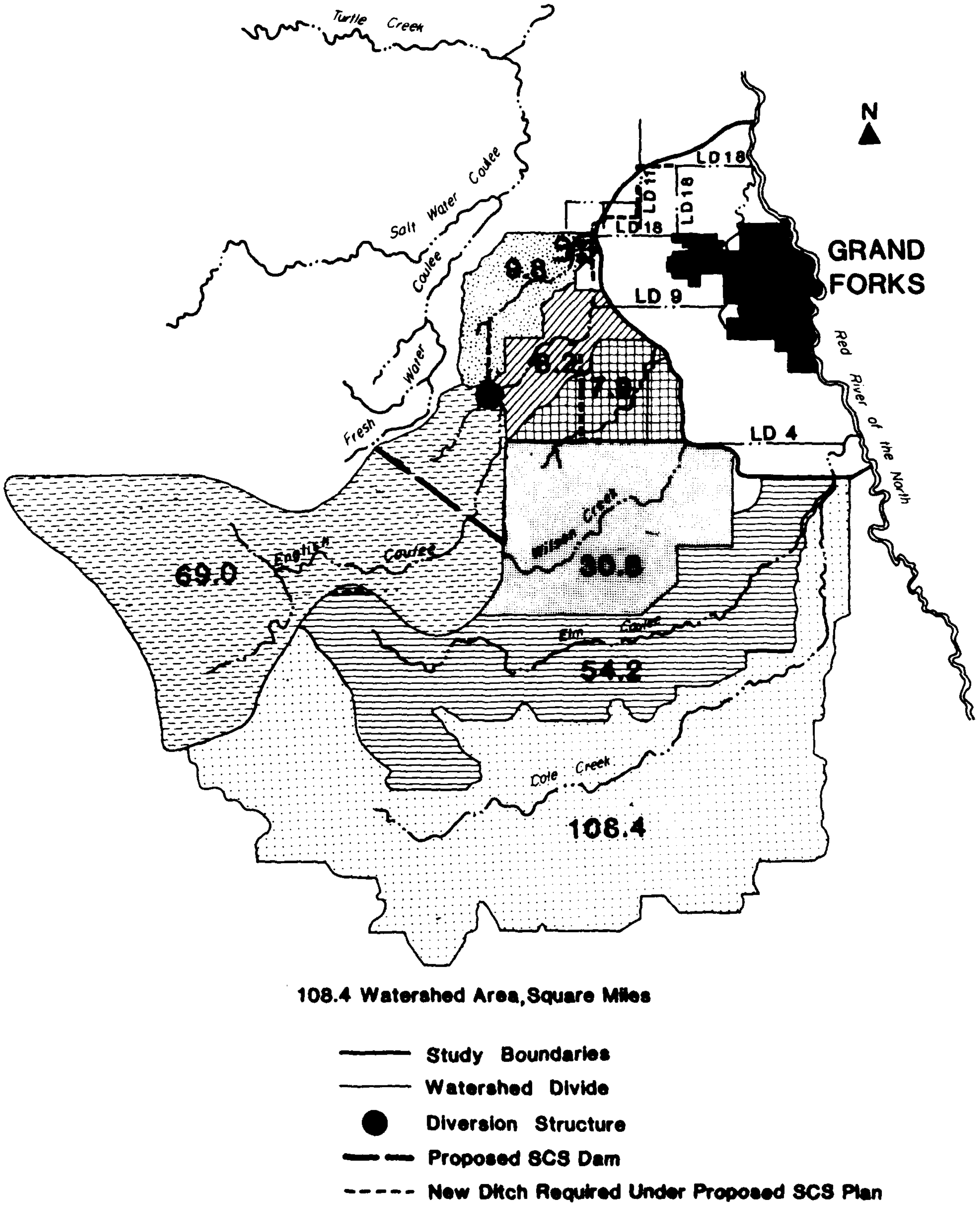

FIGURE 18

TRIBUTARY WATERSHED MAP

Legal aspects of interbasin transfer of waters and inundation of lands not previously subject to flooding must be investigated before the SCS plan could be implemented. If the plan is implemented, impacts on urban flooding would be significant. Large portions of drainage areas which discharge through the city would be cut off, correspondingly reducing peak flows. Furthermore, the timing of these peaks may be altered so that synergistic benefits are felt downstream. Consider, for instance, a possible effect on the spring snowmelt runoff. Characteristically, the spring runoff peak from English Coulee precedes that of the Red River - in 1979, the difference was about 5 days. If the SCS plan advanced peak flows from the English Coulee watershed enough, runoff from the coulee and Legal Drain 18 might be over before the Red River crested. Therefore, it might be possible to greatly reduce the pumping capacity and hence the cost of the closure structure/pumping station proposed for handling the outflow from the legal drain and coulee.

WATER SUPPLY

INTRODUCTION

Major communities within the study area depend on the Red Lake and Red Rivers as their sole source of water supply to meet the demands of residential, commercial, and most industrial users. Smaller communities and many rural residents rely on groundwater supplied by individual wells and/or three rural water supply associations.

Stage 2 studies concluded that the groundwater sources of the two rural water supply associations for which information was available (the Agassiz Water Users Association and Grand Forks-Traill Water Users, Inc.) should have adequate supplies of good quality water through the study's time frame (1980-2030). Conclusions were not possible regarding the third association (the Marshall and Polk Rural Water System) and independent water users. The stage 2 report recommended that all three associations and other self-supplied water users continue to supply their own needs rather than join a regionalized system. Thus, in stage 3, attention was focused on

the water supply situation in the cities of Grand Forks and East Grand Forks plus the Grand Forks Air Force Base, which gets its water from Grand Forks.

The major concern is the perceived lack of dependability of existing water sources to meet present and future needs. In past years, low river flows have seriously threatened the reliability of the Red Lake and Red Rivers as dependable sources of water. The cities felt a need to explore alternative sources and treatment systems to provide a dependable water supply.

This urban area is a major service, education, and agricultural product processing center. Agricultural production near the area has become more centralized and has grown significantly. The agricultural processing industry has also grown, creating more jobs. The jobs attract more people who demand more services. Unlike the rural areas of North Dakota and Minnesota, the urban area is growing rapidly. The urban population, agricultural processing industries, and service industries are projected to grow and expand. Without an adequate supply of water, the urban area cannot continue its healthy growth. Economic and industrial growth will be hindered. A no-growth situation may occur or population growth may continue without jobs so the socioeconomic character of the area may decline. At a minimum, the area may be forced to suffer through water shortages.

PROBLEMS, NEEDS, CONCERNS, AND OBJECTIVES

Overview

The following problems, needs, concerns, and objectives regarding water supply have been identified for Grand Forks and East Grand Forks:

- Adequacy of water supply - The ability of the Red and Red Lake Rivers in conjunction with the regulation of reservoirs on these river systems to meet existing and future water needs for urban Grand Forks and

East Grand Forks, particularly during drought years similar to those of the 1930's, is questioned. Total residential, commercial, and industrial demands on surface waters are expected to more than double from 1976 to 2030. In the same period, water demands from other urban and rural users in the Red and Red Lake River basins will also be growing, possibly consuming so much of these rivers' waters that little would reach Grand Forks and East Grand Forks.

- Adequacy of existing water treatment process - National primary and secondary standards for drinking water have been enacted pursuant to the Safe Drinking Water Act (Public Law 93-523). In addition, the EPA is considering regulating organic chemical contaminants which would have to be removed by advanced surface water treatment.

- Adequacy of existing water treatment system - The low-head dams that pool water on the Red and Red Lake Rivers for the cities' intakes need periodic maintenance and replacement; the Red River dam will need replacement in about 1990. East Grand Forks intakes in the Red Lake River pool equal the plant capacity of 4 mgd (million gallons per day) which will be matched by demand in 2005. Current treatment capacity available to Grand Forks and East Grand Forks is 12 and 3 mgd, respectively. Grand Forks' maximum day water demands already equal the plant capacity; expansion is needed immediately, but space at the existing site is very limited. East Grand Forks' plant cannot reach its rated capacity of 4 mgd because of hydraulic constraints. The maximum daily demand in East Grand Forks is projected to reach 4 mgd in 2005 after which plant expansion will be needed.

- Adequacy of major water transmission lines - The existing transmission lines for the Grand Forks and East Grand Forks area are adequate but need maintenance and replacement on a regular basis. The Grand Forks Air Force Base, however, depends on one supply line for its water. If this line were to rupture or become unusable, a water shortage could occur.

Urban Water Demands

Residential and commercial water demands in Grand Forks and East Grand Forks, like those in most cities, are cyclical - highest demands occur in summer with lawn care, car washes, swimming pools, more showers, etc. Industrial water demands in the two cities, however, have an essentially countervailing cycle. The largest industrial water users process agricultural products beginning with the fall harvest of sugar beets, potatoes, and sunflowers. The high water use period for these industries usually runs from about September or October to May. Besides the municipal water intakes on the Red and Red Lake Rivers, the American Crystal Sugar plant and Burlington Northern industrial park area, both in East Grand Forks, have independent intakes on the Red Lake River. Monthly consumption by these users is highly seasonal, primarily because of sugar beet processing at the American Crystal Sugar plant.

Table 7 shows the monthly water demands in 1976 as an example. The overall water demand on the two rivers is less variable than usual because of the out of phase water demand cycles; the ratio of maximum day to average day demand is reduced. Therefore, the water treatment and distribution systems of the cities are used more efficiently. This is also important in that water treatment plants are normally designed to meet maximum daily demands; thus, the plant capacity need not be oversized as much as might be the case to handle maximum demand.

Urban water demand projections are based on analyses of current demands, interviews with water users, population projections, land use projections, and assumptions regarding improved industrial efficiencies, increased agricultural processing, and new industries.

Table 7 - 1976 urban water withdrawals from Red River of the North and Red Lake River

User	Source	Water use in month (million gallons)												Annual daily average (mgd)
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
East Grand Forks	Red Lake River	35.25	33.75	35.52	28.50	36.61	36.56	44.24	41.12	37.49	35.54	33.61	34.09	1.18
Grand Forks	Red River	186.64	168.04	179.94	183.78	238.95	218.94	248.68	248.12	210.92	217.71	204.33	198.52	6.86
American Crystal Sugar	Red Lake River	17.89	7.99	2.13	0	0	0	0	51.81	20.04	51.67	10.29	0.32	0.44
Burlington Northern	Red Lake River	9.55	8.68	8.68	8.68	6.94	3.47	-	0.88	1.74	2.60	6.94	6.94	0.18
Total		249.33	218.46	226.27	220.96	282.50	258.97	292.92	341.93	270.19	307.52	255.17	239.87	8.66
Percent daily use is of annual daily average		93	87	84	85	105	100	109	127	104	115	98	89	-

Table 8 summarizes projected annual average daily water demands for the urban area based on the above considerations. These average daily demands were used to size water supply sources and compute operation and maintenance costs.

Table 9 presents the projected maximum daily water demands for the urban area based on historical trends. The maximum daily demand could occur in May, June, July, or August; for design purposes, it was assumed to occur in June when agricultural processing water demands are lowest. These projections assume the current maximum day to average day demand ratios of 1.72 and 1.86 for Grand Forks and East Grand Forks, respectively, will not change. These maximum daily demands were used to size water treatment and transmission facilities. It was assumed that the self-supplied industries continued to supply their own needs.

Table 8 - Projected average day urban water demands

	Annual average daily demand (mgd)					
	1980	1990	2000	2010	2020	2030
Grand Forks:						
Residential and commercial[1]	4.54	5.35	6.21	7.23	8.40	9.74
Major industrial	3.17	3.24	3.43	3.60	3.77	3.93
Subtotal	7.71	8.59	9.64	10.83	12.17	13.67
East Grand Forks:						
Residential and commercial[1]	0.93	1.07	1.24	1.45	1.68	1.95
Major industrial	0.57	0.64	0.71	0.77	0.84	0.91
Subtotal	1.50	1.71	1.95	2.22	2.52	2.86
Total public supply from surface water	9.21	10.30	11.59	13.05	14.69	16.53
Self-supplied industries using surface water	0.63	0.63	0.63	0.63	0.63	0.63
Total surface water demands (cfs)	9.84 (15.22)	10.93 (16.91)	12.22 (18.90)	13.68 (21.16)	15.32 (23.70)	17.16 (26.55)
Self-supplied industries using groundwater	0.15	0.15	0.15	0.15	0.15	0.15
Total urban water demand	9.99	11.08	12.37	13.83	15.47	17.31

(1) Average day use is based on population projections times 100 gpcd (gallons per capita per day). Includes water consumed by customers, unaccounted distribution system losses, and wasted filter backwash water.

Table 9 - Projected maximum day urban water demands

	Maximum day demand (mgd) [1]					
	1980	1990	2000	2010	2020	2030
Grand Forks:						
Residential and commercial [2]	11.06	12.40	14.04	15.92	18.05	20.46
Major industrial [3]	2.20	2.37	2.54	2.71	2.88	3.05
Subtotal [4]	13.26	14.77	16.58	18.63	20.93	23.51
East Grand Forks:						
Residential and commercial [2]	2.59	2.91	3.29	3.72	4.21	4.77
Major industrial [3]	0.20	0.27	0.34	0.41	0.48	0.55
Subtotal [5]	2.79	3.18	3.63	4.13	4.69	5.32
Total public supply from surface water	16.05	17.95	20.21	22.76	25.62	28.83
Self-supplied industries using surface water	--	--	--	--	--	--
Total surface water demands	16.05	17.95	20.21	22.76	25.62	28.83
(cfs)	(24.83)	(27.77)	(31.26)	(35.21)	(39.63)	(44.60)
Self-supplied industries using groundwater	--	--	--	--	--	--
Total urban water demand	16.05	17.95	20.21	22.76	25.62	28.83

(1) Maximum day could occur in May, June, July, or August. The maximum day used for design is projected to occur in June when the major industrial user demands are low.
(2) Difference between total city and major industrial.
(3) Estimated from 1976 and 1977-78 records and escalated for new industrial growth.
(4) Maximum day is based on a ratio of total city average to maximum of 1.72.
(5) Maximum day is based on a ratio of total city average to maximum of 1.86.

Urban Water System Facilities

Figure 19 is a schematic of the existing water supply, treatment, and distribution facilities serving the urban area. The municipal systems of Grand Forks and East Grand Forks are interconnected, so treated water can be transferred between the cities. Under current arrangements, transfers would occur only during emergencies; no transfers have been made.

Grand Forks obtains its water from the Red and Red Lake Rivers. A blend of both waters is proportioned to optimize treatment. Grand Forks has two raw water intakes on the Red River with 6.5-mgd capacity at Intake No. 1 and 10.0-mgd capacity at Intake No. 2. The Red Lake River raw water intake (intake No. 3) has an 8.9-mgd capacity. A low-head dam at Riverside Park pools water on the Red River. This dam has recently been repaired; the repair is projected to extend its useful life through about 1990. Also, a low-head dam on the Red Lake River just upstream from its confluence with the Red River pools water for the Grand Forks Red Lake River intake and the East Grand Forks intake.

The Grand Forks water treatment plant provides pretreatment, softening, filtration, and disinfection before distribution. The current water treatment plant was originally built in 1958, expanded in 1968, had multimedia added in 1976 to the 1958 plant, and had sludge handling processes installed in 1977. The plant is operated on a 24-hour per day basis.

Hydraulic constraints limit the rated capacity of the Grand Forks water treatment plant to 12 mgd. The current maximum day demand experienced at Grand Forks also is approximately 12.0 mgd. Therefore, an expansion is needed to meet future demands. The existing plant is located near the downtown business district in a completely built-up area. A small area is available on the existing site, but a major expansion would require the purchase and removal of one or more blocks of residential housing or location at a new site.

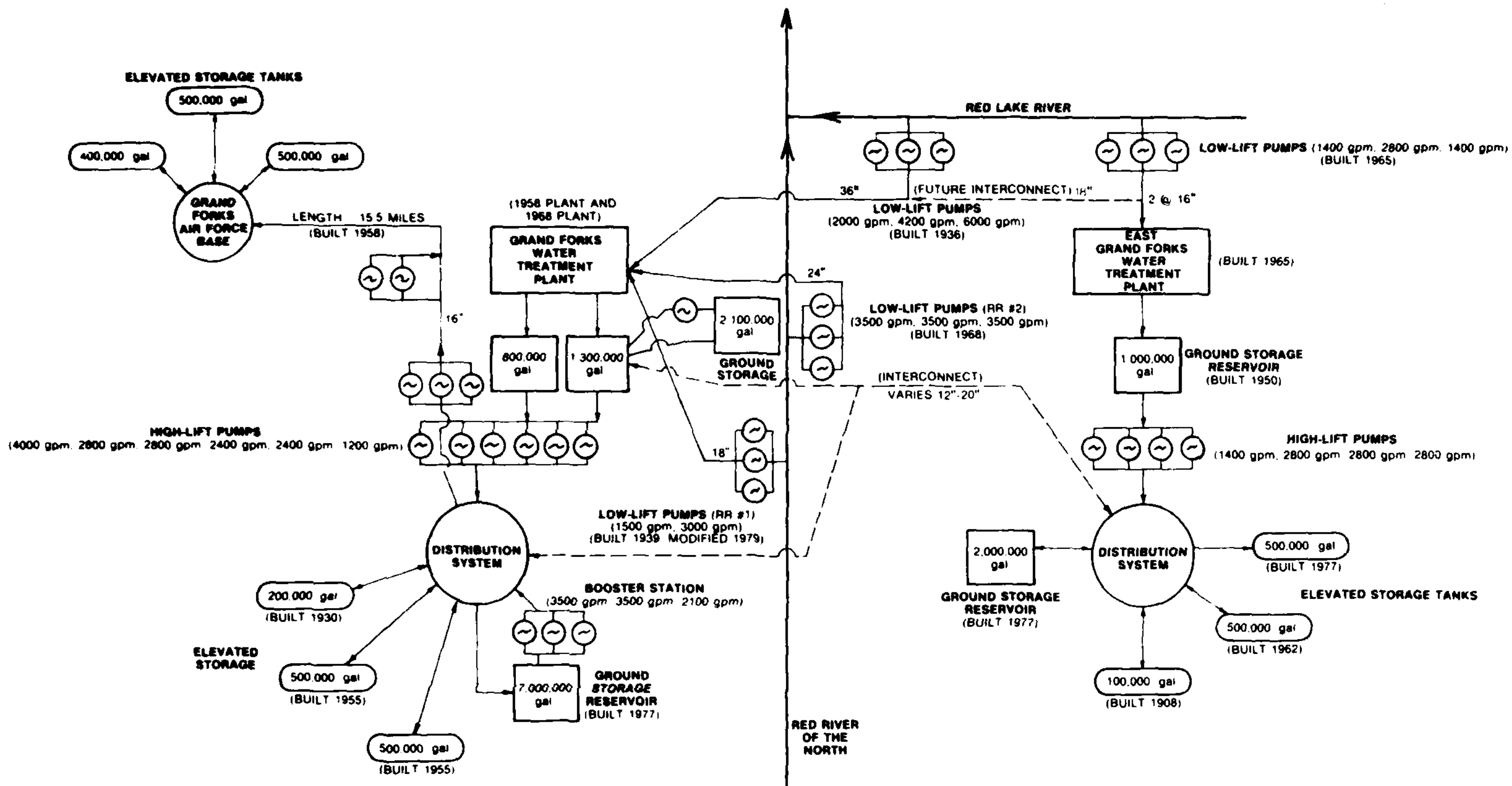

FIGURE 19 - Schematic of Existing Water System Facilities

The water transmission lines and treated water storage facilities are shown on figure 19. Grand Forks has recently installed a 7-million gallon ground storage reservoir on the west side of the city. This brings the total city storage capacity to 12.4 million gallons. The Grand Forks Air Force Base has 1.4 million gallons of storage. Only one water transmission line serves the Air Force base. This line has experienced a number of breaks and leaks as a result of action of corrosive soils on the cast iron pipe.

East Grand Forks obtains its water from the Red Lake River through a 4.0-mgd raw water intake. The low-head dam on the Red Lake River just above its confluence with the Red River pools water for the intake. An intake for East Grand Forks on the Red River has been proposed. However, this project is not proceeding at this time.

Like the Grand Forks water treatment plant, the East Grand Forks plant provides pretreatment, softening, filtration, and disinfection before distribution. However, because the quality of Red Lake River water is better, one-stage (rather than two-stage) softening is provided. The water treatment plant is operated 8 to 10 hours a day.

The East Grand Forks water treatment plant was built in 1962 and has a rated capacity of 4.0 mgd. When the flow rate exceeds 3.0 mgd, the plant experiences some difficulty in holding the softening basin sludge blanket. The present maximum day demands are approximately 2.0 mgd, so this operating difficulty has not been much of a problem; East Grand Forks is currently considering measures to correct this problem. The maximum day demand is projected to reach 4.0 mgd in about 2005. The plant will have to be operated 24 hours per day by 2005 to meet maximum day demands. Undeveloped land adjacent to the East Grand Forks plant could be used for expansion.

The water transmission and storage facilities are shown on figure 19. East Grand Forks has recently completed construction of a 2-million-gallon storage reservoir and a 500,000-gallon elevated storage tank. These facilities bring the total city storage capacity to 4.1 million gallons.

The above review of existing facilities indicates that several improvements will be required in the near or relatively near future:

- For Grand Forks - Immediate expansion of the existing water treatment capacity to serve future demand. Land area at and/or near the existing plant is limited.

- For the Grand Forks Air Force Base - Installation of a second water transmission line from Grand Forks to the base for increased reliability.

- For Grand Forks, East Grand Forks, and the Air Force base - Replacement and maintenance of existing facilities such as water intakes, transmission lines, treatment facilities, and distribution systems.

- For East Grand Forks - Modification of the existing water treatment plant to ensure that it can treat 4.0 mgd.

- For Grand Forks - In about 1990, replacement of the low-head dam near Riverside Park which pools water on the Red River of the North.

- For East Grand Forks - Construction of a water intake structure to obtain water from the Red River of the North.

- For East Grand Forks - Increased hours of operation as demands increase; expansion of the existing water treatment plant when its capacity is exceeded.

- For Grand Forks - Expansion of water treatment facilities when their capacity is exceeded.

Water Supply Source Alternatives

A water supply source should be capable of supplying an adequate quantity of raw water which can be easily treated. In the absence of raw water supply storage facilities, the source should be capable of supplying maximum day demands. With raw water storage, the source should be capable of supplying average day demands. A relatively good quality raw water can be more easily treated, minimizing costs and increasing reliability.

Based on stage 2 studies, three potential water supply sources were considered:

- Red River of the North and Red Lake River surface water, including in-channel and/or off-channel storage.

- Garrison Diversion water augmenting Red River of the North flow.

- Elk Valley aquifer groundwater.

In addition, other groundwater sources in the general vicinity were examined and water conservation was evaluated as a means to reduce maximum and average daily demands.

The Water and Power Resources Service's (formerly the Bureau of Reclamation) Garrison Diversion project is a multipurpose water resources project designed to divert Missouri River water into central and eastern North Dakota. The water would be used to irrigate agricultural land, provide municipal and industrial water supplies, furnish recreational opportunities, and develop fish and wildlife management programs. The project was originally authorized as part of the multipurpose program included in the Flood Control Act of 1944 and was reauthorized in 1965 by Public Law 89-108.

The total Garrison Diversion project provided for the irrigation of 250,000 acres and the annual transfer of 510,000 acre-feet of water for municipal and industrial needs, fish and wildlife conservation, and recreation. However, the total plan has been challenged on the basis that the

quantity and quality of return flows may adversely affect the environment and the potential uses of the receiving streams. Canada is primarily concerned that the return flows may injure health and property in Canada and introduce foreign biota.

A Final Comprehensive Supplementary Environmental Statement dated February 1979 compared six alternatives that would reduce the size of the 1965 authorized project. A reduced scope Garrison Diversion project would include 96,300 acres of irrigation, municipal water service to 15 communities, recreational development in 5 areas, and development of lands for fish and wildlife management. About 225,000 acre-feet of water would be diverted annually. The plan would transfer water to the Sheyenne River in the Red River basin. This water would augment the quantity of water available to the Grand Forks-East Grand Forks urban area. This water would eventually enter Canada.

The final environmental impact statement on the Garrison Diversion project indicates that the water quality of the Red River would be changed very little under the recommended plan and would increase by only minor amounts under the original total plan. The mean monthly concentrations of total dissolved solids, sulfates, and hardness would increase slightly, but the stream's water uses would not be affected.

An alternative to transfer water only to the James River basin which drains into the Missouri River was not considered in the final supplementary environmental statement. However, discussions with Water and Power Resources personnel indicate that a reasonable approach for implementing the Garrison Diversion project could be:

- A pilot project would divert flow to the James River. Long-term monitoring of the water quality, fauna, and flora would identify environmental impacts.

- If no significant adverse environmental impacts occur in the James River, diversion of water to the Souris River basin would be undertaken along with long-term monitoring.

- If environmental objections are overcome, water would be diverted to the Red River of the North basin.

Recently (May 1981), a U.S. District judge ruled that the State of North Dakota and Federal Government could not proceed with construction of the Garrison Diversion project until Congress reauthorized the plan. As of this writing, the ultimate impact of this decision is uncertain. Likewise, the eventual effect of the administration's push for resource development and countervailing budget cutting proposals remains in question.

The above discussion indicates that the Garrison Diversion project cannot be relied on to help meet Grand Forks' and East Grand Forks' urban area water demands. If the environmental and political constraints can be overcome, the project may be reactivated and completed. However, this is unlikely in the near future.

Groundwater is obtainable in the Grand Forks-East Grand Forks urban area from bedrock and overlying glacial drift deposits. However, most of the sources are not satisfactory because of water quality, water quantity, and aquifer yield limitations.

Bedrock aquifers in the area are generally characterized by low well yields, small storage volumes, and highly mineralized water. The Dakota bedrock aquifer can produce higher yields, but the water is primarily used for livestock watering because of its poor quality. Bedrock aquifers were not suitable for supplying the urban area's water needs and were not considered further.

The major glacial drift aquifers near the Grand Forks-East Grand Forks urban area are shown on figure 20. In general, only the Elk Valley, Inkster, and Beach Ridge aquifers contain relatively good quality water. The other aquifers were not considered further because they contain very saline water, have relatively small storage volumes, or exhibit low well yields. The Inkster aquifer was not considered further because it has a

relatively small storage volume and recharge area. Also, the Inkster aquifer is currently used by a rural water district and local farmers.

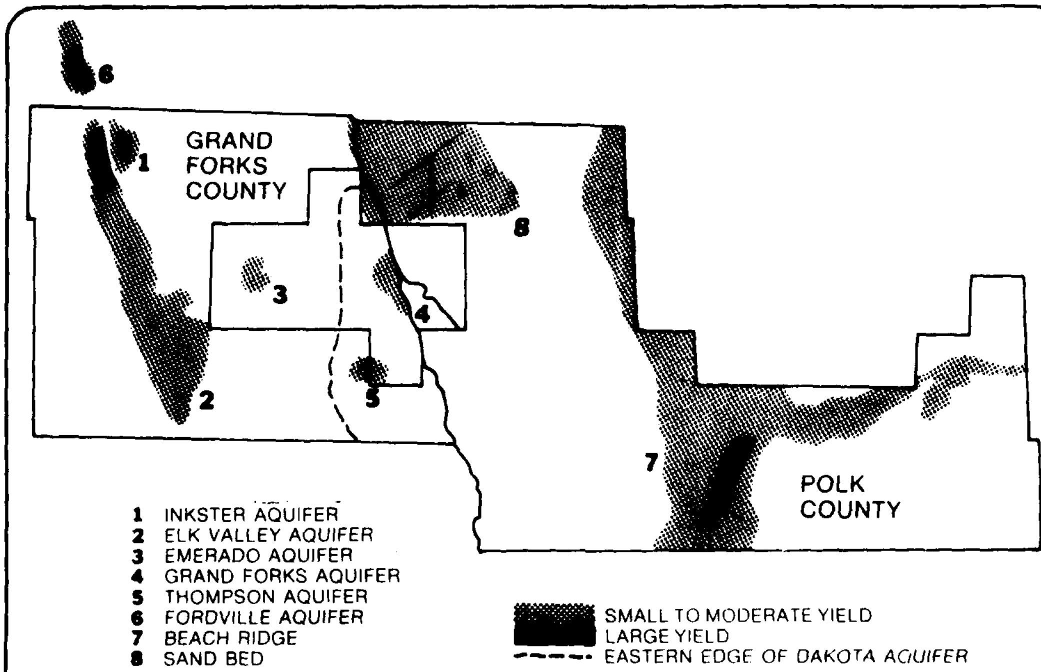

FIGURE 20 - Major Glacial Drift Aquifers, Grand Forks and Polk Counties

The Grand Forks-East Grand Forks urban area is located in a semiarid region of the United States where the mean annual precipitation is about 20 inches per year. Only about 2 inches of this precipitation will recharge the glacial drift aquifers and be available as a source of water supply. The year 2030 Grand Forks-East Grand Forks municipally supplied average day water demands were projected at 16.53 mgd (18,517 acre-feet per year). Therefore, approximately 175 square miles of recharge area would be required to satisfy the projected derands if all the recharge could be used for Grand Forks-East Grand Forks water supply.

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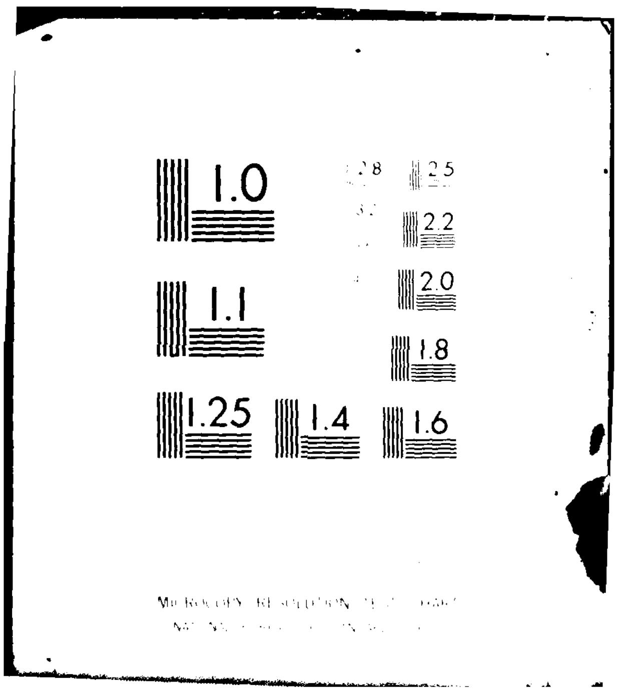
1.0
2.8
2.5
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2.0
1.1
1.8
1.25
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The Elk Valley aquifer is the best groundwater source near the urban area. However, major constraints limit its use. Over 85 percent of the aquifer area would be required to satisfy the projected year 2030 average day municipal water demand. Analysis indicates that wells would be spaced on 10,000-foot centers. Construction costs, rights-of-way, easements, and institutional arrangements would be major constraints.

The cities of Larimore and Northwood, North Dakota, use the Elk Valley aquifer as their sole source of supply. The city of Ardoch, North Dakota, located on the Forest River, uses the aquifer discharge as a water supply source. Numerous farmers use the aquifer for domestic uses, livestock watering, and some irrigation purposes. The aquifer's storage volume is relatively small, so water cannot be "mined." The North Dakota State Water Commission has expressed serious reservations over allowing the Grand Forks-East Grand Forks urban area to use the Elk Valley aquifer. More detailed studies would have to be made to determine the availability of water, existing water users, and recharge rates for the aquifer. However, it is unlikely that the urban area could use the entire Elk Valley aquifer at the exclusion of other users.

Use of the Elk Valley aquifer as a supplemental source of supply was eliminated because of high costs. A well field system and 30 to 35 miles of transmission pipelines would have to be constructed. During stage 2, it was estimated that a well field and transmission pipeline would cost about $35 million to meet all publicly supplied urban water demands and about $20 million to meet 50 percent of these demands.

The Beach Ridge aquifers are a series of long, narrow deposits of sand and gravel that mark the various stages of former glacial Lake Agassiz. These aquifers are located in Minnesota and North Dakota; however, larger deposits have been located along the east banks of the former Lake Agassiz in Minnesota. Deposits in Grand Forks County exhibit low yields, small storage volumes, large water level fluctuations, and wells that have gone dry. Therefore, these deposits were not considered further. The city of Crookston, Minnesota, has obtained a water use permit from the Minnesota Department of Natural Resources to

use a Beach Ridge aquifer in Polk County to supply its average day demands of about 1,050 gpm (gallons per minute) (1.5 mgd) and maximum day demands of about 1,750 gpm (2.5 mgd). The proposed source is about 12 miles east of Crookston. Crookston's analyses indicate that the recharge rate to the aquifer would be about 2 inches per year.

As with the Elk Valley aquifer, the primary consraints to the use of the Beach Ridge aquifers in Polk County to supply Grand Forks-East Grand Forks water needs are the recharge rate, the distance (about 40 miles), and sharing the water with other users. It must be concluded that the Beach Ridge aquifers are not a reliable supply source for the urban area water demands.

Use of the Beach Ridge aquifers as a source of supply for just East Grand Forks was investigated. East Grand Forks average day water demand is projected to be about 2,000 gpm (2.86 mgd) in the year 2030, about 17 percent of the total urban area demand. However, the same physical, institutional, and economic constraints to using the Beach Ridge aquifer exist: East Grand Forks is about 37 miles from the known Beach Ridge aquifers, a recharge area of 30 square miles would be needed, and bad conflicts with existing users and land management of the recharge area would be problems. Although the size of the transmission pipeline would be smaller, the cost would still be prohibitively high. Therefore, the Beach Ridge aquifers are not a feasible water supply source for East Grand Forks.

The Red River of the North and the Red Lake River are the only surface water sources in the vicinity of Grand Forks and East Grand Forks capable of meeting the urban area's water demands. Reservoirs constructed in the early 1950's to regulate flows on the two rivers have significantly changed streamflow characteristics. Therefore, historical U.S. Geological Survey stream gaging records are not adequate to define future low-flow conditions. The three multipurpose reservoirs used for low-flow augmentation are:

- Red Lakes Reservoir on the Red Lake River, Minnesota. The initial control structure was built in 1931; that structure was replaced in 1952.

- Orwell Reservoir on the Ottertail River, Minnesota - completed in 1953.

- Lake Ashtabula (Baldhill Dam) on the Sheyenne River, North Dakota - completed in 1950.

A detailed low-flow frequency analysis was conducted as part of the urban study. That analysis statistically analyzed simulated low-flow events in the Red River of the North at Grand Forks and the Red Lake River at East Grand Forks. The objective of the analysis was to define the availability of surface water and the need for supplemental in- and/or off-channel storage to cope with the selected design event - a 50-year drought. A secondary objective was to determine the year when supplemental storage or an offsetting reduction of water demands would become necessary to cope with the 50-year drought.

The low-flow condition analyzed assumed year 2030 water demands and existing reservoir operation. Input data for the low-flow frequency analysis were generated by the Hydrologic Engineering Center's HEC-3 computer program, "Reservoir System Analysis for Conservation." This program simulated monthly average flows for the period of record from 1930 to 1976.

The frequency-mass curve analysis procedure used to analyze the simulated monthly flows involved two steps. First, low-flow frequency curves were computed by sequential analysis of the minimum average flows for various durations. Then, a mass curve was constructed for the specified design frequency.

A family of low-flow frequency curves was derived from the HEC-3 simulated monthly flows using the HEC program, "Partial Duration - Independent Low-Flow Events." This program analyzed flows of any given duration throughout the period of record. The flows were arranged in ascending order of magnitude and statistically analyzed. The return frequency for each

flow duration was computed by Beard's Method. This HEC program was satisfactory for developing discharge-frequency curves for durations between 2 and 12 months; discharge-frequency curves for durations of 7 days, 14 days, 1 month, 24 months, 48 months, and 96 months were computed by other procedures.

The partial duration analyses and adjustments resulted in a family of low-flow discharge-frequency-duration curves. These curves were used to develop mass curves of the streamflow available for water supply. (Mass curves are composites of flow for all durations for a specified design frequency.) The urban area's water demands were superimposed on the mass curve; the point of maximum divergence between the demand curve and each mass curve yielded the reservoir storage requirement for that mass curve's design frequency. In accordance with common practice, storage requirements obtained by this method were increased 10 percent.

The HEC-3 computer run used for the low-flow frequency analysis predicted that the Red River of the North could satisfy Grand Forks and East Grand Forks year 2030 water demands and also meet minimum downstream flow requirements for the entire simulated 1930-1976 period of record except for 1 month - August 1936. The Red Lake River could not satisfy East Grand Forks year 2030 water demands and meet downstream requirements only 2 months - during simulated August and September 1936 conditions. These shortages result because the water level in the Red Lakes Reservoir fell below its designated minimum conservation pool at which point the reservoir operating plan calls for reducing the discharge from an average rate of 50 cfs to a maximum discharge of 15 cfs. These discharges are specified by the provisions of a treaty with the Red Lake Band of the Chippewa Indians.

The extreme low flows that occurred during the 1930's are within the 47-year period of record (1930-1976) analyzed by the HEC-3 program. On the basis of the partial duration analysis and Beard's plotting methods, the extreme events have a recurrent frequency of less than 70 years for durations of 12 months or less. However, the evidence is overwhelming that a longer recurrence frequency should be assigned to these extreme events. Analyses performed by the Corps using the HEC-4 computer program "Monthly Streamflow Simulation" stochastically extended the 40 years of streamflow data by generating 400 years of synthetic data. However, the 1930's drought could not be reproduced.

The USGS presented the results of a study of the frequency of low flows on the Red River in a 1962 report. The report concluded that, although evidence may not be adequate to warrant assignment of a definite recurrence interval to the minimum flows of the 1930's, the minimums were probably the lowest that occurred during a period of at least 150 years.

On the basis of the above considerations, it was concluded that the extreme low-flow events should be assigned a 200-year recurrence interval.

The results of the partial duration analysis for the Red River of the North at Grand Forks and the Red Lake River at East Grand Forks indicate that the Red Lake Reservoir has a significant effect on streamflow. At recurrence intervals greater than 10 to 20 years, reservoir low-flow augmentation releases maintain higher flows than have historically been observed. Other computer runs had shown that releases from Lake Ashtabula and Orwell Lake do not have a significant impact on the water supply of Grand Forks and East Grand Forks. Therefore, the computer run used for the low-flow analysis assumed these two reservoirs were operated only for communities upstream of the urban area. However, Red Lakes Reservoir was operated in its normal fashion to satisfy Grand Forks and East Grand Forks water demands.

Figures 21 and 22 present the mass curves for the Red River of the North at Grand Forks. Streamflow mass curves for 20-, 50-, and 100-year recurrences are shown. The mass curves were obtained from the family of discharge-frequency-duration curves by multiplying the average flow rate by the duration. These quantities were adjusted to allow 8 cfs to pass Grand Forks. (Earlier studies had determined that 8 cfs was a reasonable minimum base flow to provide a safety factor and insure that minimal river flow would be maintained below the withdrawal point.) The Grand Forks and East Grand Forks year 2030 water demand curve was superimposed on streamflow mass curves. The net quantity of supplemental water supply storage required for each design event was given by the maximum divergence between the demand curve and the respective streamflow curve. An allowance of 10 percent was added in accordance with the frequency-mass curve analysis procedure.

The HEC-3 program did not account for evaporation losses associated with in- and/or off-channel storage volumes. Evaporation losses were based on a rate of 28 inches per year and were estimated to be about 5.6 inches in 1 month and about 34.5 inches in 450 days. Evaporation depends on the reservoir surface area. In-channel storage has a relatively large surface area because the river slopes are relatively flat. In-channel storage surface areas pooled behind the low-head dams are about 600 acres on the Red River of the North and 200 acres on the Red Lake River. Off-channel reservoirs could be designed to greatly reduce the surface area.

Figure 22 indicates that water supply shortages would be experienced for approximately 30 days during a 50-year drought event. The storage requirements for various drought return frequencies would be:

	In-channel storage			
		Evaporation		
Drought return frequency (years)	Base storage required (acre-feet)	Duration (days)	Loss (acre-feet)	Total storage required (acre-feet)
20	60	17	180	240
50	130	29	370	500
100	180	35	450	630

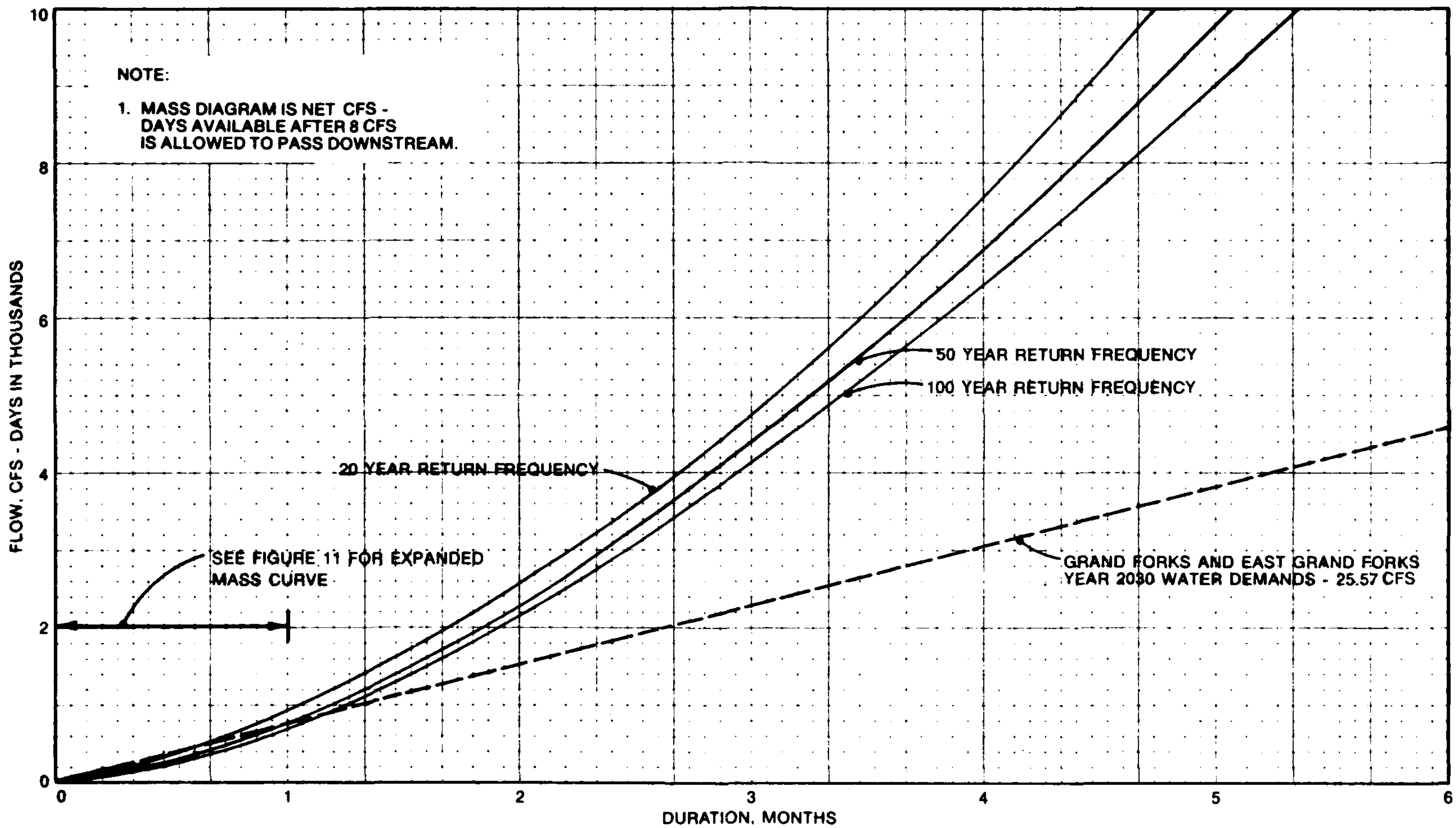


FIGURE 21 - Mass Curve for the Red River of the North at Grand Forks

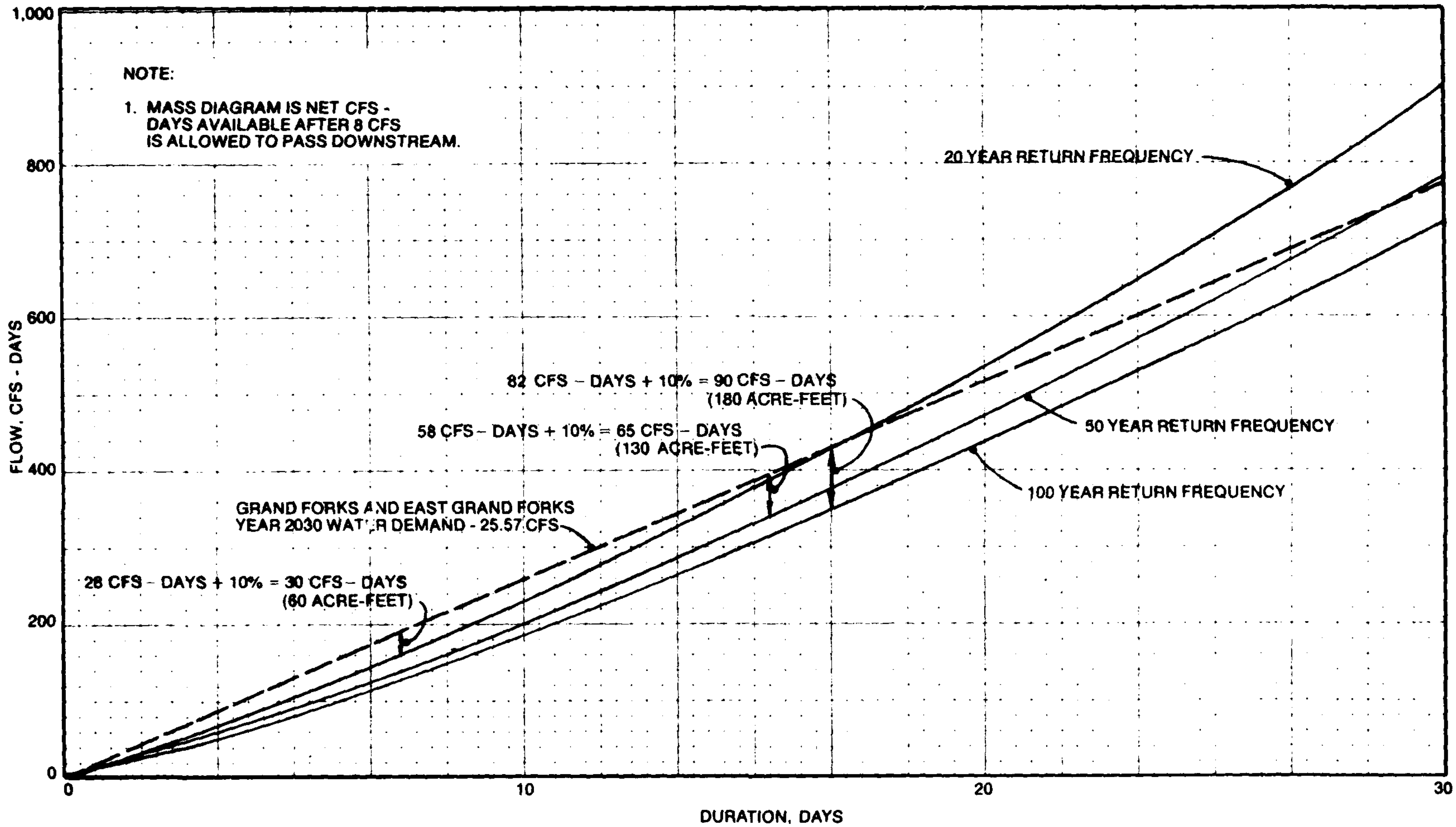


FIGURE 22 - One Month Duration Mass Curve for the Red River of the North at Grand Forks

Off-channel storage reservoirs were also considered. Evaporation would add less than 2 acre-feet of storage based on 17 days duration, 5 acres of surface area, and a 15-foot working depth. For 35 days duration, evaporation would add about 7 acre-feet of storage to the base storage required based on 15 acres of surface area and a 15-foot working depth.

Figure 23 presents the mass curves for the Red Lake River at East Grand Forks. The mass curves for 20-year, 50-year, and 100-year return frequencies are shown and include an adjustment for the minimum of 3 cfs that earlier reports recommended be allowed to pass below East Grand Forks. The water shortages and the volume of in-channel storage required to satisfy East Grand Forks demands during various drought return frequencies would be:

Drought return frequency (years)	In-channel storage: Base storage required (acre-feet)	Evaporation: Duration (days)	Evaporation: Loss (acre-feet)	Total storage required (acre-feet)
20	380	186	420	800
50	520	270	450	970
100	720	450	610	1,330

Evaporation losses were based on the Red Lake River 200-acre storage pool. If off-channel storage reservoirs were used, evaporation losses would add about 60 acre-feet of storage based on 180 days duration, 30 acres of surface area, and a 15-foot working depth. For 450 days duration, evaporation would add about 150 acre-feet of storage based on 50 acres of surface area and a 15-foot working depth.

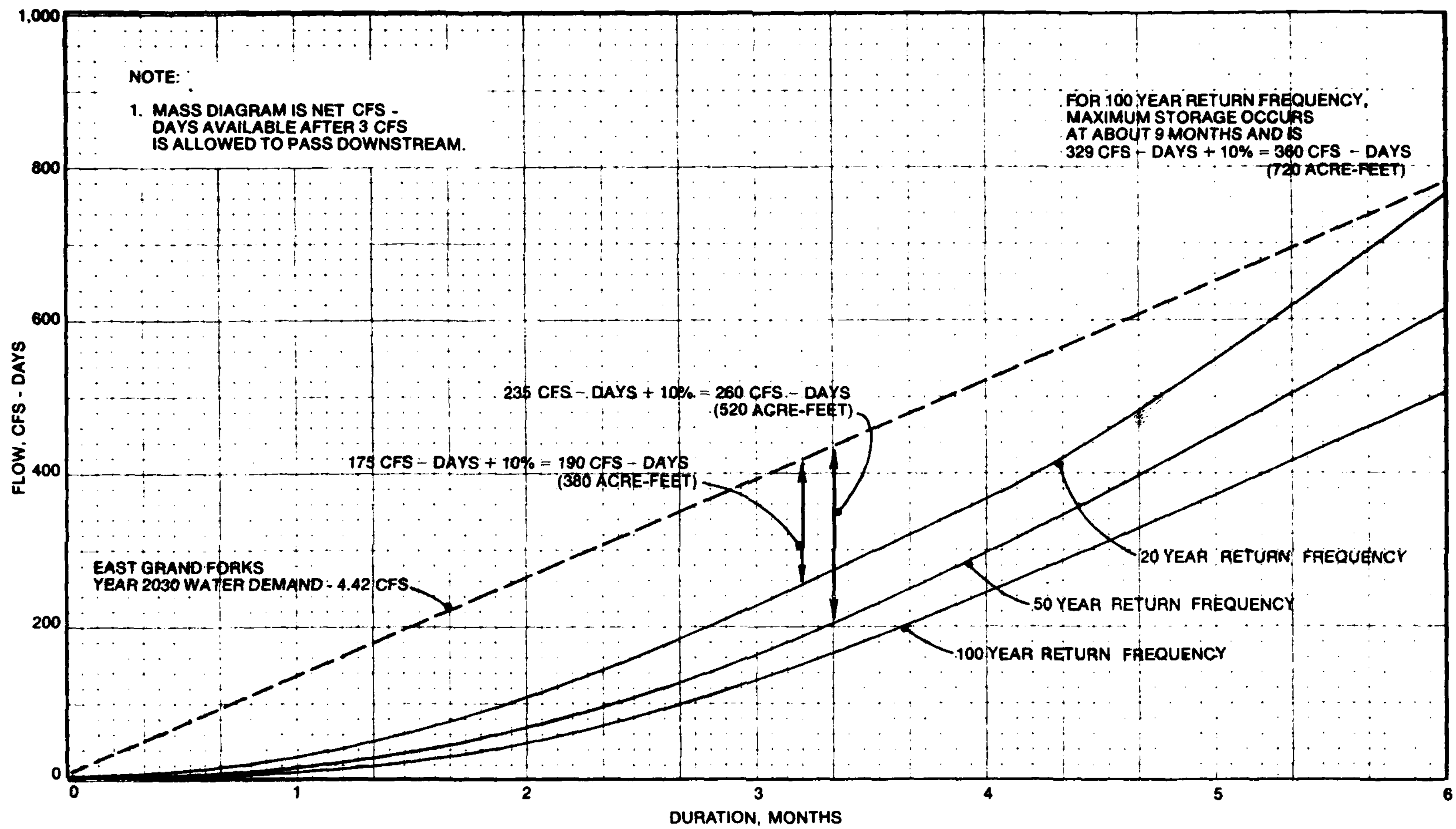


FIGURE 23- Mass Curve for the Red Lake River at East Grand Forks

The available in-channel storage pooled behind the existing low-head dams on the Red River of the North and the Red Lake River was estimated to be 2,200 acre-feet and 1,000 acre-feet, respectively, a total of 3,200 acre-feet. This estimate was based on cross sections and thalweg elevations surveyed in 1944, 1972, and 1979 that indicate that river channel elevations have not varied greatly with time. An allowance of 5 feet for sediment buildup between high-flow scours was provided for in the estimated storage volumes.

The above analysis indicated that the combined Red River of the North and Red Lake River flows plus existing in-channel storage could satisfy Grand Forks and East Grand Forks urban area projected water demands and required supplemental storage for the 50-year design drought (and for droughts with at least the 100-year return frequency) through year 2030. Therefore, no additional in- or off-channel storage is needed. Continued maintenance and/or replacement of the low-head dams is important for maintaining in-channel storage capacity.

For the Red Lake River serving just East Grand Forks, river flow and in-channel storage could satisfy East Grand Forks projected water demands and supplemental storage needs through year 2030 for up to the 50-year return frequency drought. To satisfy the 100-year drought, 330 acre-feet of additional in- or off-channel storage would be required. If an off-channel storage facility was selected to provide the additional 330 acre-feet, the total land area for water storage, dikes, and access was estimated to be about 60 acres. East Grand Forks could satisfy these supplemental storage needs by constructing a backup water intake in the Red River of the North to draw on the pool behind the existing low-head dam. However, since the design drought is the 50-year recurrence event, additional provisions for supplemental storage are not recommended.

The HEC-3 model was operated for various water demand and reservoir discharge conditions. The range of water demands included projected needs in 1980, 1990, 2000, and 2030. In general, changing water demands have minor impact on the streamflow at Grand Forks and East Grand Forks. Regardless of demand, there was always one period of shortage requiring supplemental storage because the water level in the Red Lakes Reservoir fell below its minimum conservation pool and water releases were reduced from 50 cfs to 15 cfs. However, the magnitude of the shortage increased with greater water demands.

The evaporation losses over the 450-square-mile surface area of the Red Lakes Reservoir had a more significant impact on the streamflow than downstream water demands. One computer run operated the Red Lakes Reservoir to discharge 50 cfs rather than 15 cfs even when the operating level fell below the minimum conservation pool. All water demands could be satisfied and no shortages resulted. Furthermore, releasing 50 cfs did not significantly affect the water level in the Red Lakes Reservoir.

In summary, the low-flow augmentation reservoirs built and improved in the early 1950's can maintain streamflows except during drought periods when in-channel storage supplements natural streamflows to meet the urban area's water demands. The existing in-channel storage capacity is adequate to meet projected year 2030 water demands during the design 50-year drought. The need for a new or supplemental water source - the Garrison Diversion project or an aquifer - is obviated.

The low-flow frequency analysis indicates that, to meet projected year 2030 water demands, supplemental storage is required for all droughts with a return frequency greater than about 10 years. Partial duration analyses for projected 1980, 1990, and 2000 water demands were not conducted; however, it is evident that supplemental storage would be required even for 1980 demands because, when Red Lakes Reservoir releases are reduced from 50 to 15 cfs, essentially none of the released flow reaches the urban area.

The Red and Red Lake Rivers exhibit similar water quality characteristics according to the data collected between 1953 and 1977. The Red River of the North has higher total dissolved solids, hardness, alkalinity, and suspended solids. Total dissolved solids concentrations follow a seasonal pattern - they are low during periods of high flow and high during periods of low flow. The Red Lake River experiences higher average biological organism concentrations and higher fecal coliform counts. At low flow, the concentration of total dissolved solids and hardness greatly exceeds average values.

Both rivers experience extensive periods of high turbidity, due mainly to the very fine silty clay streambeds. Fluctuating river levels and currents cause turbulence which resuspends colloidal clay particles. Also, runoff from agricultural lands adds to the suspended solids levels. Suspended solids concentrations tend to be lower during periods of low flow and higher during high flows.

Water treatment plant operators in Grand Forks indicate that Red Lake River water is a little easier to treat because of its normally lower hardness levels. Both the Grand Forks and East Grand Forks water treatment plants remove suspended solids, color, taste, odor, and hardness. During high flows, higher dosages of chemicals are required to remove suspended solids and taste and odor problems. During low flows, higher chemical dosages are required because of higher hardness levels.

FORMULATION OF ALTERNATIVES

Source

Studies have shown that there is only one satisfactory source of water to meet the urban area's needs - surface water from the Red River of the North and Red Lake River. Therefore, this section focuses solely on formulation of alternatives based on these sources.

Water from the Garrison Diversion project is a possibility. However, because of international and environmental concerns, many years will be spent on pilot studies of the effects of interbasin transfers before water could be diverted into the Red River of the North basin. Groundwater sources, including the promising Elk Valley and Beach Ridge aquifers, cannot meet the urban area's demands because of inadequate recharge rates, low well yields, small storage, or highly saline water.

Water Treatment Regulations

All public water systems must comply with the Federal Safe Drinking Water Act (Public Law 93-523), which gave the EPA the authority to establish national drinking water quality standards. The established standards are divided into primary and secondary regulations. The primary regulations pertain to water quality problems that affect the health of consumers. The secondary regulations deal primarily with aesthetic qualities of drinking water.

The National Interim Primary Drinking Water Regulations became effective on 24 June 1977. An amendment to the primary standards proposed on 9 February 1978 would add regulations for organic chemical contamination. Following a National Academy of Sciences study of human health effects from exposure to contaminants in drinking water, revised National Interim Drinking Water Regulations will be promulgated. Secondary Drinking Water Regulations were enacted by the EPA on 19 July 1979. Secondary regulations are not federally enforceable and are intended as guidelines for the States.

The National Interim Primary Drinking Water Standards set maximum contamination levels for 10 inorganic chemicals, 6 organic pesticides and herbicides, 2 categories of radionuclides, turbidity, and coliform organisms.

One of the major reasons for implementing the Safe Drinking Water Act was to determine the effect of certain organic chemicals on human health and how best to control contamination. Chlorinated organic chemicals are suspected of being carcinogens. Organic chemical contaminants in drinking water are derived from two principal sources:

- Chlorination practices at the water treatment plant (trihalomethanes (TTHM) and many other chemicals).

- Direct or indirect industrial discharges, agricultural sources (pesticides), and urban and agricultural runoff.

The EPA has enacted a regulation setting a maximum concentration level for total TTHM's; a proposed regulation specifies, for synthetic organic chemicals, a treatment technique requiring granular activated carbon or its equivalent.

The TTHM regulation applies to systems serving 10,000 or more persons that use a disinfectant in water treatment. The TTHM regulation is to take effect 2 years after enactment for systems serving more than 75,000 persons. Systems serving 10,000 to 75,000 persons will be required to comply 4 years after the enactment date. Systems serving less than 10,000 persons are not required to comply with the maximum contamination levels or monitor. The proposed treatment regulation requires water systems serving greater than 75,000 persons to use granular activated carbon or its equivalent in their drinking water treatment systems.

Considerable discussion and study has taken place concerning the proposed organic chemical contaminant regulations. Arguments include demonstration of human health effects, costs, treatment technology, research adequacy, and universality of compliance. The final form of these regulations can only be speculated.

The proposed National Secondary Drinking Water Regulations set standards which are not federally enforceable. High concentrations of these constituents are not known to cause any serious health hazard. However, aesthetics which should be considered include red water due to iron, bad taste and odor, laxative effects, scaling, and other problems which may discourage public use.

The Federal Safe Drinking Water Act allows individual States to obtain authority from the Environmental Protection Agency for setting and enforcing water quality standards. State standards may be more stringent than those of the Environmental Protection Agency, but not less stringent. The agency also encourages the States to enforce the Secondary Drinking Water Standards. Both North Dakota and Minnesota have accepted the authority and have enacted State laws establishing the necessary legal and administrative structure. Also, both States have indicated that they will accept responsibility for implementing the proposed organic chemical contaminant regulations when they are finalized.

Water Treatment Alternatives

Figure 24 shows the plan view of a universal water treatment plant that could satisfy all existing and proposed water quality standards for the water supply sources being considered. Each source contains different contaminants, so the plant design would be established by deleting unneeded processes from the typical plant.

The processes required for normal treatment of surface water are similar to those used by Grand Forks and East Grand Forks. Grand Forks uses pre-treatment and two-stage softening; two-stage softening was an experimental process designed to treat the high magnesium hardness found in Red River water. East Grand Forks uses pretreatment and one-stage softening to treat Red Lake River water which is of relatively better quality. The proposed treatment processes include the unit processes shown on figure 24 for the universal water treatment plant with the following modifications:

Source	Modification
Red River of the North	No granular activated carbon treatment.
Red Lake River	No stabilization, second stage recarbonation, or granular activated carbon treatment
Combination Red River of the North and Red Lake River	Same as Red River of the North

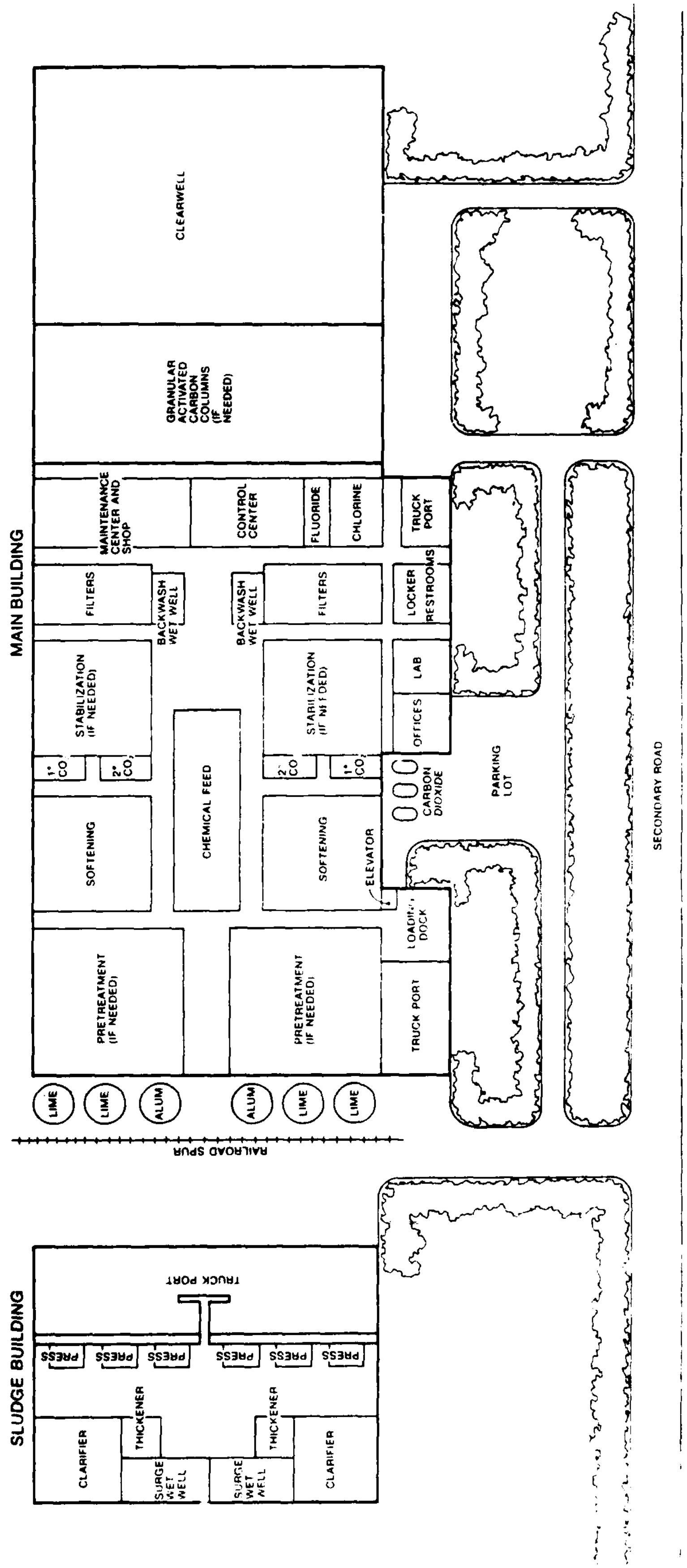


FIGURE 24 - Typical Water Treatment Plant, Plan View

If advanced surface water treatment is required to remove organic chemical contaminants, granular activated carbon treatment would have to be included. As proposed, the Environmental Protection Agency regulations would require 1 year monitoring of Grand Forks drinking water for organic chemicals. Grand Forks would have to implement the other portions of the proposed regulations in about year 2015 when its population is projected to be 75,000. The total urban area population is projected to be 75,000 in about year 2000, so a combined water supply system would be affected sooner by the proposed regulations. East Grand Forks population is projected to be 10,000 in about year 1990, so the city would be required to monitor for organic chemicals at that time.

North Dakota and Minnesota Departments of Health believe that organic chemical contaminants will not be a problem for Grand Forks or East Grand Forks. Most organics in the Red River of the North and Red Lake River are probably due to natural vegetative decay (leaves and agricultural plant residue); no major chemical industries are located in the Red River of the North basin, so synthetic organic contaminants should not be a problem. It is recommended that Grand Forks and East Grand Forks together undertake an organic chemical monitoring program to determine the concentration of organic chemicals in their raw and treated waters to provide a sound basis for justifying the need or lack of need for removing organic chemical contaminants.

The North Dakota and Minnesota Departments of Health have also indicated that most of the organics in the Red and Red Lake Rivers could probably be removed by chemical addition and sedimentation in the pretreatment basin. Therefore, by eliminating prechlorination and removing organic precursors of TTHM's before chlorination, low levels of chlorinated organics would be present in the drinking waters.

Based on the above analyses, granular activated carbon treatment would not be required under the proposed regulations. However, requirements may change to include systems serving smaller populations or lower organic chemical contaminant limits.

Water Conservation Measures

Water conservation measures reduce peak demands and total water use. When these measures are implemented, available water supply sources can be more efficiently used; the design life of existing water storage, treatment, and distribution systems can be extended; and smaller capital investments are required for expansions. General water conservation measures may be implemented at any time. More drastic measures may be implemented during drought conditions to save even more water.

An effective water conservation program is a multifaceted approach directed at and implemented by the general public, service organizations, industries, local governments, and water utilities. Table 10 discusses a range of water conservation measures which can be implemented. Generally, five basic techniques are used:

- Reduction in treatment plant losses and distribution system leaks.
- Public awareness and education programs.
- Ordinances for mandating water use reduction.
- Pricing changes to discourage water waste.
- Industrial water conservation.

Reduction in water treatment plant losses can be achieved by recycling filter backwash and clarifier sludge draw-off water. Grand Forks has recently installed sludge handling facilities which dewater sludges and recycle the carrier water to the head end of the water plant. Therefore, water losses are minimal. East Grand Forks diverts its filter backwash and clarifier sludge waters to the sanitary sewer system. It is estimated that 15 percent of the raw water drawn from the river is lost. East Grand Forks should take steps to reduce this water loss.

Table 10 - Methods of urban water conservation - implementation, advantages, and disadvantages

Techniques to Reduce Water Consumption	Implementation	Advantages	Disadvantages
Leak detection and repair of water agencies' distribution systems.	Institutional	1. Reduces unaccounted water losses. 2. Reduces undermining damage to streets, sidewalks, and other structures.	1. Because leaking water often percolates to usable ground water, water agencies sometimes ignore losses. 2. Low cost of lost water may not equal cost of detection and repair.
Leak detection and repair of consumers' systems.	Voluntary Institutional	1. Can reduce other home repair costs such as those from wood rot. 2. Many leaks simple and inexpensive to repair. 3. Reduces operational costs.	1. Difficult to induce flat-rate consumers and apartment dwellers to repair leaks. 2. Could be expensive to consumer if he needs professional service.
Education	Voluntary Mandatory Institutional	1. Induces voluntary water conservation. 2. Changes long established, wasteful consumer habits. 3. Achieves long-lasting results by influencing younger generation. 4. Ensures greater success and acceptance of other water saving means.	1. Effective program requires coordinated efforts of local and state agencies.
Efficient irrigation using automatic devices	Voluntary	1. Healthier plants. 2. Decreased maintenance. 3. Mechanical type savings.	1. Periodic adjustments required. 2. Expensive initial cost.
Native and other low-water-using plants in landscaping.	Voluntary Institutional	1. Established native and other low-water-using plants need little or no irrigation. 2. Established plants need little care.	1. General preference for exotic plants. 2. Narrow selection of native plants in nurseries. 3. Difficult to establish some low-water-using plants and general lack of knowledge on care. 4. Somewhat higher costs because native and other low-water-using plants are not readily available.
Modification (retrofit) of existing plumbing fixtures.	Mandatory Voluntary Institutional	1. Many devices are nominal in cost. 2. Enables water and energy conservation in existing facilities and therefore has potential rapid, widespread savings. 3. Water savings mechanically effected. 4. Reduces wastewater conveyance and treatment load.	1. Inconsistent effectiveness of retrofit devices because of variable design and construction of existing fixtures. 2. Consumer removal or tampering with retrofit devices because of suspected poor performance. 3. Some devices require skilled installation and/or follow-up adjustment. 4. May cause blockage problems in marginal sewage collection systems.
Water saving plumbing fixtures in new and replacement construction.	Mandatory	1. Mechanical devices render savings despite user habits. 2. Reduce wastewater conveyance and treatment load.	1. Possible resistance to redesign and retooling to manufacture water conserving devices. 2. Drain pipe slope tolerances are more critical. 3. Initially, consumers may resist acceptance. 4. Initially, higher unit cost of water saving devices until demand increases production and reduces cost. 5. May cause blockage problems in marginal sewage collection systems.
New technology.	Voluntary Institutional	1. Greater water and energy savings than conventional designed devices. 2. Reduce wastewater conveyance and treatment load.	1. Uncertain long-term effectiveness. 2. Consumer and institutional resistance to innovations. 3. Higher initial costs. 4. Conformance with existing codes and regulations; may require changes or variations. 5. May cause blockage problems in marginal sewage collection systems.
Metering	Institutional	1. Easier to implement than some of the other suggested methods. 2. May induce consumers to begin conserving water.	1. Consumer objection. 2. High capital cost. 3. Requires changes in rate structure and billing procedure.
Sewer service charges based on water consumption.	Institutional	1. More equitable than flat-rate basis to pay operational cost of sewage treatment. 2. Achieve dual benefits of reduced water consumption and wastewater flow.	1. Requires well designed rate structure. 2. Need to segregate inside and outside water consumption.
Pricing	Institutional	1. May be relatively easy to implement. 2. Can affect all customers. 3. Can be strong inducement to effect consumer savings.	1. Consumer objection. 2. Requires well designed pricing structure to achieve effective, equitable pricing. 3. Often require changes in rate structure, meter reading, and billing procedures.

Source: Reference 46

Reduction in distribution system losses reduces the amount of water that is unaccounted for; i.e., water delivered to the distribution system but not recorded by water meters for billing purposes. Grand Forks and East Grand Forks experience 5 to 10 percent unaccounted-for water loss (which is relatively low). Grand Forks and East Grand Forks should continue existing programs and implement additional water system maintenance programs as part of their overall system management. These programs can include water main replacement, leak detection, and meter maintenance.

Public awareness and education programs are the most important facets of a water conservation program. They promote personal and community involvement. Educational techniques should be designed to enlist the active and voluntary participation of the general public. People should understand where their water comes from and that water is a limited resource. They should realize that water treatment and distribution systems are expensive to maintain and expand and that they will benefit economically by conserving water. Public awareness and education should be carried out through schools, the news media, water bill inserts, pamphlets, newsletters, workshops, and service organization projects.

Residential programs can be directed at reducing wasteful water practices. Leakage within the home (due mostly to worn out faucet washers and toilet tank valves which are easily repaired by the homeowner) represents 5 to 10 percent of all residential water consumption. Water-saving devices use less water without changing water use habits and can be installed as new plumbing fixtures are retrofitted into existing fixtures. Residential water use can be reduced by 16 to 20 percent when toilet displacement devices and shower head flow restrictors are installed.

Ordinances for mandating water use reduction are probably the most effective means for ensuring that water conservation measures are taken. Ordinances can be designed to reduce peak demands and/or total water use. Reducing peak demands has the most beneficial impact on water supply and treatment facilities. Peak demands can be reduced by regulating use and

when uses occur. This type of regulation affects primarily outdoor uses such as lawn and garden watering, car washing, swimming pool filling, and water fountains. Ordinances to reduce total water use include plumbing codes that require water-saving devices in new construction and remodeling to replace existing fixtures.

Pricing changes to discourage waste are effective in encouraging water conservation. Both Grand Forks and East Grand Forks have declining block rate structures where the unit price decreases as the total use increases. Although the declining block rate is widely used, this structure does not encourage water conservation. A variety of other pricing systems could be used: a lesser declining block rate, a uniform rate, a peak load rate, or an increasing block rate would reduce total water use. These rates affect larger users most. Peak load rates affect seasonal uses such as lawn watering.

Industrial water conservation can produce the single largest reduction in total water use. For example, representatives of American Crystal Sugar have indicated that they can double their production without increasing water consumption at their East Grand Forks plant by using water-saving equipment and recycling.

Substantial water savings can be achieved by simply eliminating unnecessary and wasteful practices. Each industry and industrial plant has different potentials for implementing water conservation measures depending on type of process, condition of equipment, education of the labor force, and commitment of management. Some measures involve capital and labor expenditures. The projected year 2030 industrial water use is about 30 percent of the total urban area water use. Most of the industrial water use occurs between September and May following the fall harvest. It is estimated that industrial water conservation measures can save 10 to 20 percent of the industrial water use or about 3 to 6 percent of the total urban area water use.

Table 11 shows projected average and maximum day urban demands with a comprehensive, effective water conservation program. This table should be compared with tables 8 and 9 which reflect projections without conservation. Average day water use could be reduced approximately 8 percent during nondrought conditions; maximum day demands could be reduced about 10 percent. These reductions can be expressed in other ways:

- The year 2030 total water use could be reduced by about 1.3 mgd or approximately 13,000 more people could be served without increasing year 2030 water demand projections.

- The year 2030 water treatment plant capacity could be reduced by about 10 percent or 3.0 mgd.

- The existing East Grand Forks plant could satisfy demands through year 2015, 10 years beyond current projections.

Table 11 - Projected urban water demands with water conservation

	Water Demands (mgd)					
	1980	1990	2000	2010	2020	2030
Annual Average Day:[1]						
Grand Forks	7.09	7.90	8.87	9.96	11.20	12.58
East Grand Forks	1.38	1.57	1.79	2.04	2.32	2.63
Total Public Supply from Surface Water	8.47	9.47	10.66	12.00	13.52	15.21
Self-Supplied Industries Using Surface Water	0.58	0.58	0.58	0.58	0.58	0.58
Total Surface Water Demand	9.05	10.05	11.24	12.58	14.10	15.79
(cfs)	(14.00)	(15.55)	(17.39)	(19.46)	(21.80)	(24.42)
Self-Supplied Industries Using Ground Water	0.14	0.14	0.14	0.14	0.14	0.14
Total Urban Demand	9.19	10.19	11.38	12.72	14.24	15.93
Maximum Day:[2]						
Grand Forks	11.93	13.29	14.92	16.77	18.84	21.16
East Grand Forks	2.51	2.86	3.27	3.72	4.22	4.79
Total Public Supply from Surface Water	14.44	16.15	18.19	20.49	23.06	25.95
Self-Supplied Industries Using Surface Water	--	--	--	--	--	--
Total Surface Water Demand	14.44	16.15	18.19	20.49	23.06	25.95
(cfs)	(22.25)	(24.98)	(28.14)	(31.70)	(35.67)	(40.14)
Self-Supplied Industries Using Ground Water	--	--	--	--	--	--
Total Urban Demand	14.44	16.15	18.19	20.49	23.06	25.95

[1] Water conservation is projected to reduce the average day demands (total water use) by 8 percent.

[2] Water conservation is projected to reduce the maximum day demands by 10 percent.

Comprehensive Water Supply Alternatives

This section develops comprehensive alternatives - total systems that pull together water supply, raw water storage, water transmission, water treatment, and management practices to satisfy the projected water demands for the Grand Forks-East Grand Forks urban area through year 2030. Each comprehensive alternative has four components corresponding to raw water source, water quality standards, water conservation practices, and separate or combined systems for the two cities. Various combinations of the four components produce the array of alternatives. A four-part number identifies each comprehensive alternative per the following system:

- Water Supply Sources

  I. Surface water from the Red River of the North and the Red Lake River
  II. Garrison Diversion water
  III. Groundwater

- Water Quality Standards

  A. Interim primary drinking water standards
  B. Proposed advanced drinking water standards

- Water Conservation Practices

  1. Without water conservation practices
  2. With water conservation practices

- Separate or Combined Systems

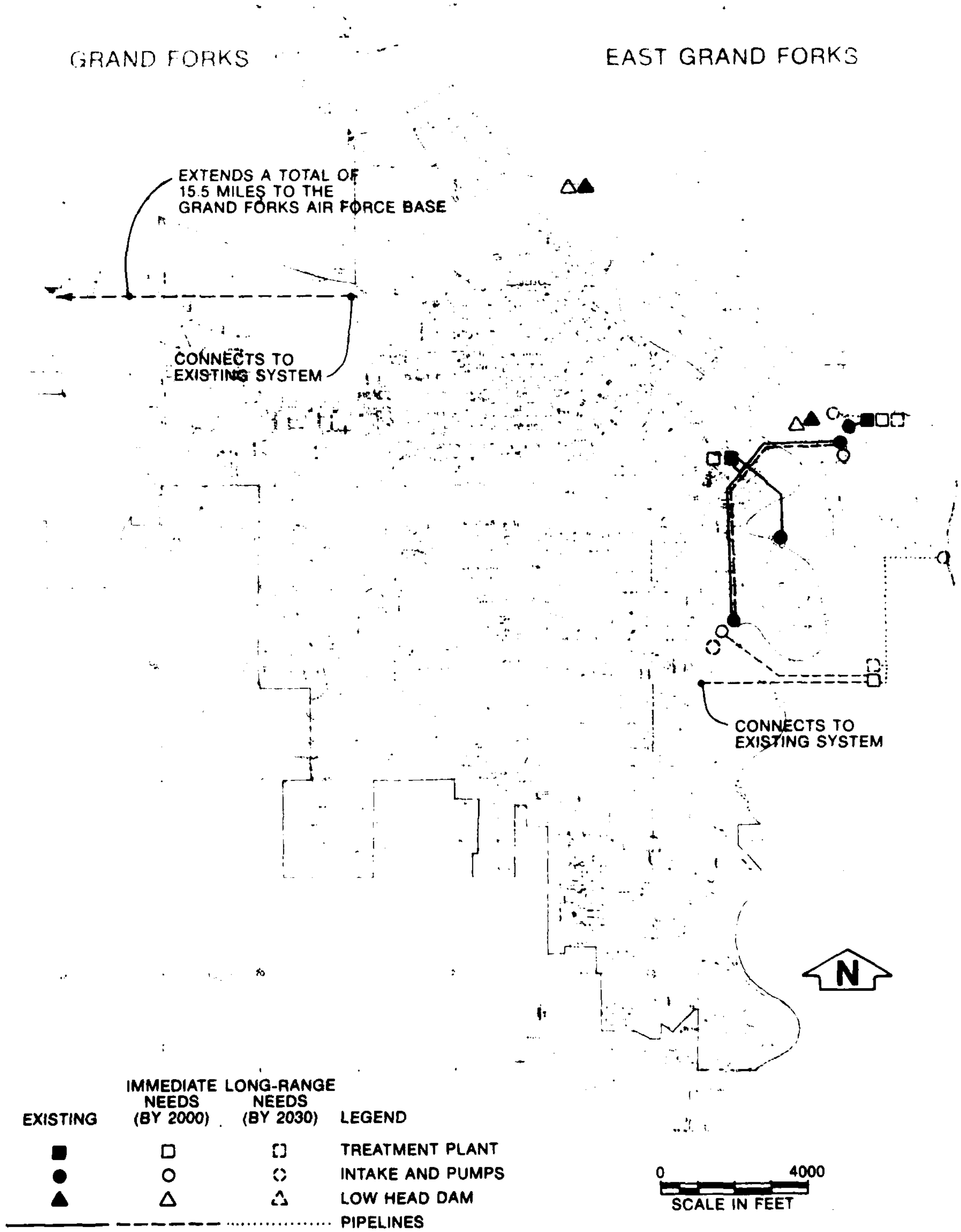
  a. Separate supply and treatment
  b. Combined supply and treatment in year 2005
  c. Combined supply and treatment in year 1990.

Component "a" assumes continuation of Grand Forks and East Grand Forks existing separate water supply, treatment, and management systems. Component "b" assumes continued separate systems until 2005, at which time new combined facilities would be built and the old facilities abandoned. Component "c" assumes construction of a new combined facility in 1990 when the service lives of the cities' water treatment plants would be over. Either of these combined systems would require a formal agreement between the participating entities specifying management and financial arrangements.

Since earlier findings demonstrated that neither the Garrison Diversion project nor groundwater could satisfactorily meet the urban area's water needs, the only viable source is surface water. Thus, all comprehensive alternatives discussed below use Red River or Red Lake River water. In all cases, Grand Forks continues to supply water to the Air Force Base; a second transmission line is installed to improve the reliability of the service. Self-supplied industries and rural water districts continue to supply their own needs. Also, since existing maximum daily water demands in Grand Forks equal the treatment plant's present capacity, an immediate increase of water supply capability is assumed.

The economic analysis of alternatives covered the 50-year study period ending in year 2030 and includes construction costs, replacement costs, operation and maintenance costs, and equivalent annual costs. All costs are based on January 1979 price levels and reflect costs in the Grand Forks and East Grand Forks area. An interest rate of 6 7/8 percent per year is used to convert costs to equivalent annual costs for the 50-year study period. Construction costs are based on maximum day demands; operation and maintenance costs are based on average day demands. Total capital costs include costs for construction, administration, engineering, legal expenses, contingencies, interest during construction, and land. Transmission mains are assumed to be routed along existing easements and rights-of-way so no additional costs will be incurred. Future construction costs, operation and maintenance costs, and salvage values are converted to equivalent present worth amounts, then to equivalent annual costs.

Conceptual plans for the 12 comprehensive alternatives are shown in figure 25. The proposed schedule of improvements, related costs, and design specifications is presented in table 12.



NOTES:

1. TABLE 12 LISTS THE SCHEDULING OF PROPOSED IMPROVEMENTS.
2. SELF-SUPPLIED INDUSTRIES AND RURAL WATER DISTRICTS WILL CONTINUE TO SUPPLY THEIR NEEDS SEPARATELY.

ALTERNATIVES 1-A-1-a, 1-A-2-a, 1-B-1-a, 1-B-2-a

CONCEPTUAL PLANS

FIGURE 25

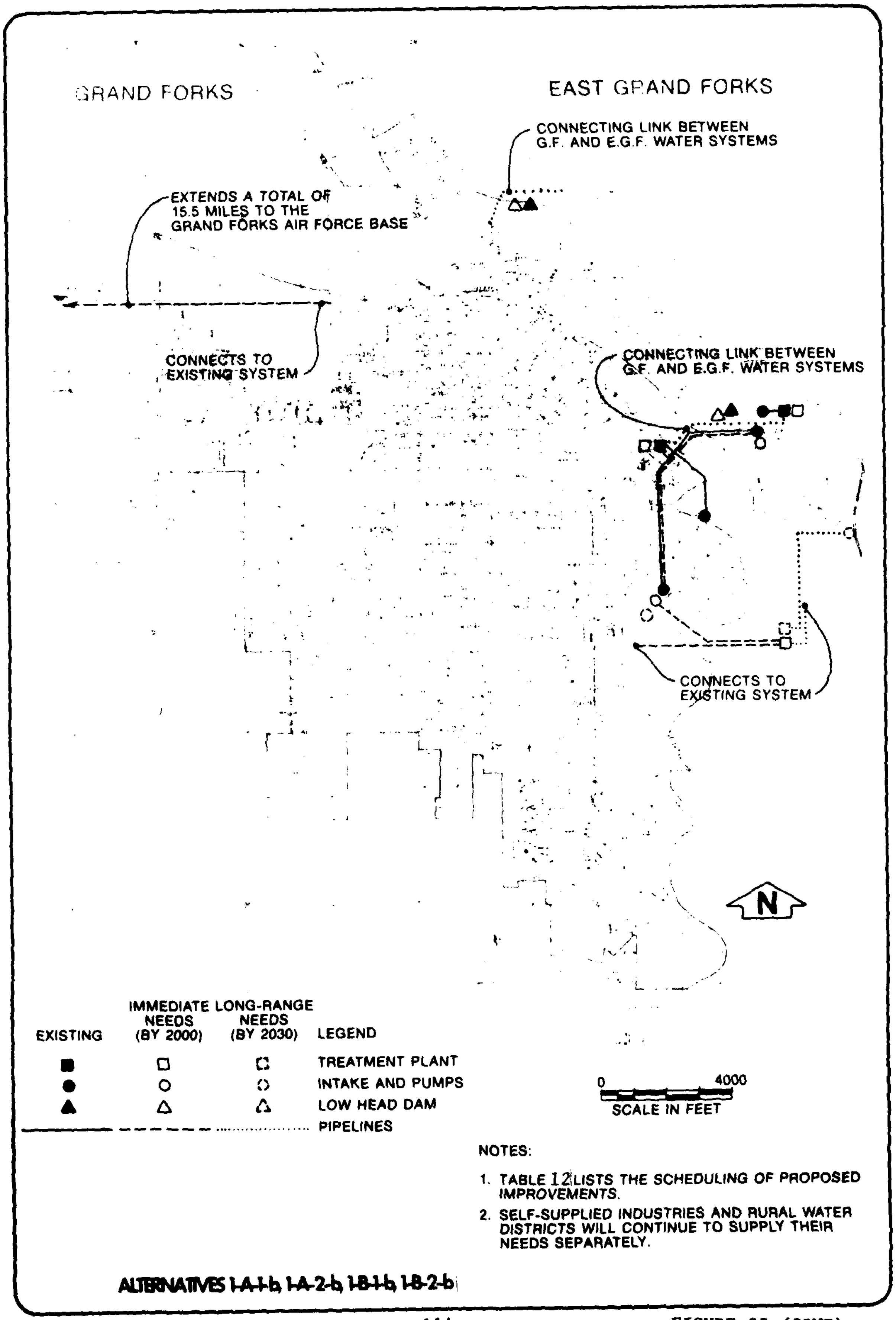


FIGURE 25 (CONT)

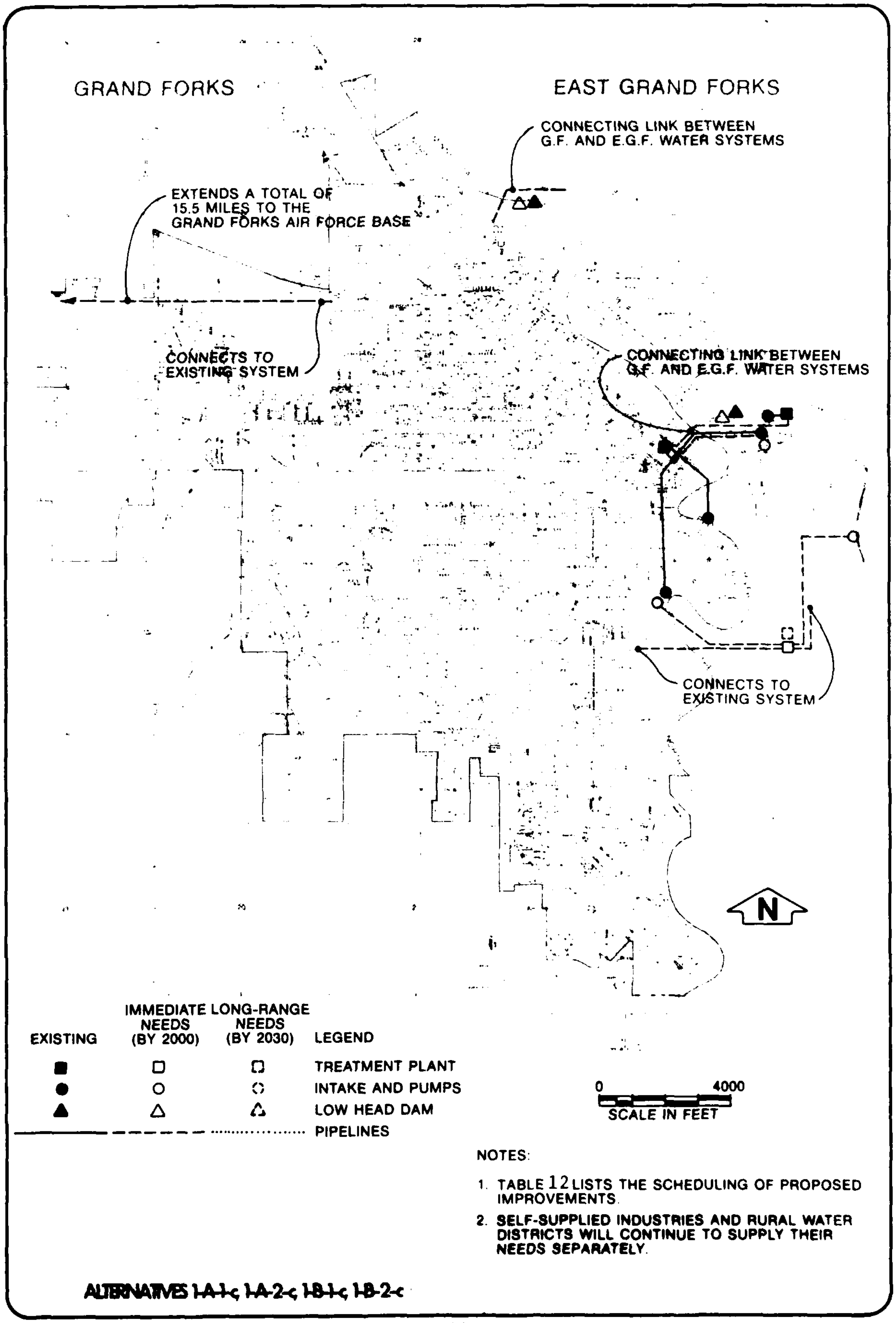


FIGURE 25 (CONT)

TABLE 12

PROPOSED IMPROVEMENTS AND COSTS

ALTERNATIVE I-A-1-a PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes(1)
Grand Forks			
1980	Capital Costs	9,670,000	New 6 mgd treatment plant and land.
		1,552,000	Supply at 6 mgd pumping (RRN).
1980	O&M Supply	25,000	For existing 7.7 mgd and new 0 mgd flow. Increases linearly to 2005 value.
1980	O&M Treatment	1,360,000	For existing 7.7 mgd and new 0 mgd flow. Increases linearly to 2005 value.
1985	Capital Cost	170,000	Refurbish GF #3 supply.
1985	O&M Storage	20,000	Maintain RRN low head dam.
1990	Capital Costs	2,510,000	Replace RRN low head dam.
		80,000	Refurbish GF #1 supply.
		6,870,000	Refurbish existing 12 mgd treatment plant.
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030.
2005	O&M Supply	36,000	Existing 7.7 mgd and new 2.6 mgd flow.
2005	O&M Treatment	2,040,000	Existing 7.7 mgd and new 2.6 mgd flow.
2005	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value
2005	Capital Costs	858,000	Expand supply to 24 mgd (RRN and RLR).
		25,900,000	New 24 mgd treatment plant.
2005	O&M Supply	2,100	For 10.3 mgd flow. Increases linearly to 2030 value.
2005	O&M Treatment	1,840,000	For 10.3 mgd flow. Increases linearly to 2030 value.
2030	O&M Supply	26,000	For 13.7 mgd flow.
2030	O&M Treatment	2,350,000	For 13.7 mgd flow.
2030	Salvage	678,000	RRN low head dam and land.
East Grand Forks			
1980	O&M Supply	5,000	For existing 1.5 mgd flow. Increases linearly to 2005 value.
1980	O&M Treatment	427,000	For existing 1.5 mgd flow. Increases linearly to 2005 value.
1990	Capital Cost	3,000,000	Refurbish existing 6 mgd treatment plant.
2005	Capital Cost	260,000	New 7 mgd supply.
		9,200,000	New 6 mgd treatment plant.
2005	O&M Supply	6,000	For 2.1 mgd flow. Increases linearly to 2030 value.
2005	O&M Treatment	314,000	For 2.1 mgd flow. Increases linearly to 2030 value.
2030	O&M Supply	8,000	For 2.9 mgd flow.
2030	O&M Treatment	630,000	For 2.9 mgd flow.
2030	Salvage	135,000	Supply.
Shared Facilities			
1985	O&M Storage	20,000	Maintain RLR low head dam.
1990	Capital Cost	3,140,000	Replace RLR low head dam.
1990	O&M Salvage	20,000	Maintain RLR low head dam in eight 5-year intervals to 2030
2030	Salvage	628,000	RLR low head dam.
Grand Forks Air Force Base			
1980	Capital Cost	6,290,000	For supply, 15.5 miles of 15" pipe from Grand Forks to base.
1980	O&M Supply	19,000	For existing 16" and new 15" pipe. Uniform to 2030.
Equivalent Annual Cost		4,460,000	

Notes: (1) Components of supply are intake structures and water transmission lines.
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually.

ALTERNATIVE I-A-2-a PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes(1)
Grand Forks			
1980	Capital Costs	7,630,000	New 4 mgd treatment plant and land
		1,362,000	New supply at 4 mgd pumping (RRN).
1980	O&M Supply	24,000	For existing 7.1 mgd and new 0 mgd flow. Increases linearly to 2005 value
1980	O&M Treatment	1,280,000	For existing 7.1 mgd and new 0 mgd flow. Increases linearly to 2005 value
1985	Capital Costs	170,000	Refurbish GF #3 supply.
1985	O&M Storage	20,000	Maintain RRN low head dam.
'90	Capital Costs	2,510,000	Replace RRN low head dam
		80,000	Refurbish GF #1 supply.
		5,030,000	Refurbish existing 12 mgd treatment plant
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030.
2005	O&M Supply	30,000	Existing 7.1 mgd and new 2.3 mgd flow
2005	O&M Treatment	1,870,000	Existing 7.1 mgd and new 2.3 mgd flow.
2005	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value
2005	Capital Costs	944,000	Expand supply to 22 mgd (RRN and RLR).
		24,200,000	New 22 mgd treatment plant.
2005	O&M Supply	26,000	For 9.4 mgd flow. Increases linearly to 2030 value
2005	O&M Treatment	1,720,000	For 9.4 mgd flow. Increases linearly to 2030 value
2030	O&M Supply	34,000	For 12.6 mgd flow.
2030	O&M Treatment	3,200,000	For 12.6 mgd flow.
2030	Salvage	1,050,000	RRN low head dam and land.
East Grand Forks			
1980	O&M Supply	4,000	For existing 1.4 mgd flow. Increases linearly to 2005 value
1980	O&M Treatment	400,000	For existing 1.4 mgd flow. Increases linearly to 2005 value.
1990	Capital Costs	3,000,000	Refurbish existing 4 mgd treatment plant.
2005	Capital Costs	264,000	New 7 mgd supply.
		8,250,000	New 5 mgd treatment plant
2005	O&M Supply	6,000	For 1.9 mgd flow. Increases linearly to 2030 value
2005	O&M Treatment	485,000	For 1.9 mgd flow. Increases linearly to 2030 value.
2030	O&M Supply	8,000	For 2.6 mgd flow.
2030	O&M Treatment	580,000	For 2.6 mgd flow.
2030	Salvage	103,000	Supply.
Shared Facilities			
1985	O&M Storage	20,000	Maintain RLR low head dam.
1990	Capital Costs	3,140,000	Replace RLR low head dam.
1990	O&M Storage	20,000	Maintain RLR low head dam in eight 5-year intervals to 2030.
2030	Salvage	627,000	RLR low head dam.
Grand Forks Air Force Base			
1980	Capital Costs	6,290,000	For supply, 15.5 miles of 15" pipe from Grand Forks to base
1980	O&M Supply	19,000	Existing 16" and new 15" pipe. Uniform to 2030
Equivalent Annual Cost		6,170,000	

Notes: (1) Components of supply are intake structures and water transmission lines.
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually.

ALTERNATIVE I-B-1-a PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes(1)
Grand Forks			
1980	Capital Costs	12,700,000	New 6 mgd treatment plant and land.
		1,552,000	Supply at 6 mgd pumping (RRN).
1980	O&M Supply	23,000	For existing 7.7 mgd and new 0 mgd flow. Increases linearly to 2005 value.
1980	O&M Treatment	1,560,000	For existing 7.7 mgd and new 0 mgd flow. Increases linearly to 2005 value.
1985	Capital Costs	170,000	Refurbish GF #3 supply.
1985	O&M Storage	20,000	Maintain RRN low head dam.
1990	Capital Costs	2,510,000	Replace RRN low head dam.
		80,000	Refurbish GF #1 supply.
		6,510,000	Refurbish existing 12 mgd treatment plant.
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030.
2005	O&M Supply	36,000	Existing 7.7 mgd and new 2.6 mgd flow.
2005	O&M Treatment	2,380,000	Existing 7.7 mgd and new 2.6 mgd flow.
2005	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value.
2005	Capital Costs	858,000	Expand supply to 24 mgd (RRN and RLR).
		33,700,000	New 24 mgd treatment plant.
2005	O&M Supply	22,000	For 10.3 mgd flow. Increases linearly to 2030 value.
2005	O&M Treatment	2,110,000	For 10.3 mgd flow. Increases linearly to 2030 value.
2030	O&M Supply	26,000	For 13.7 mgd flow.
2030	O&M Treatment	3,600,000	For 13.7 mgd flow.
2030	Salvage	678,000	RRN low head dam and land.
East Grand Forks			
1980	O&M Supply	5,000	For existing 1.5 mgd flow. Increases linearly to 2005 value.
1980	O&M Treatment	564,000	For existing 1.5 mgd flow. Increases linearly to 2005 value.
1990	Capital Costs	4,090,000	Refurbish existing 6 mgd treatment plant.
2005	Capital Costs	269,000	New 7 mgd supply.
		12,100,000	New 6 mgd treatment plant.
2005	O&M Supply	8,000	For 2.1 mgd flow. Increases linearly to 2030 value.
2005	O&M Treatment	463,000	For 2.1 mgd flow. Increases linearly to 2030 value.
2030	O&M Supply	8,000	For 2.9 mgd flow.
2030	O&M Treatment	778,000	For 2.9 mgd flow.
2030	Salvage	135,000	Supply.
Shared Facilities			
1985	O&M Storage	20,000	Maintain RLR low head dam.
1990	Capital Costs	3,140,000	Replace RLR low head dam.
1990	O&M Storage	20,000	Maintain RLR low head dam in eight 5-year intervals to 2030.
2030	Salvage	628,000	RLR low head dam.
Grand Forks Air Force Base			
1980	Capital Costs	6,290,000	For supply, 15.5 miles of 15" pipe from Grand Forks to base.
1980	O&M Supply	19,000	For existing 16" and new 15" pipe. Uniform to 2030.
Equivalent Annual Cost		5,320,000	

Notes: (1) Components of supply are intake structures and water transmission lines.
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually.

ALTERNATIVE I-B-2-a PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes(1)
Grand Forks			
1980	Capital Costs	10,000,000	New 4 mgd treatment plant and land
		1,362,000	Supply at 4 mgd pumping (RRN).
1980	O&M Supply	24,000	For existing 7.1 mgd and new 0 mgd flow. Increases linearly to 2005 value
1980	O&M Treatment	1,480,000	For existing 7.1 mgd and new 0 mgd flow. Increases linearly to 2005 value
1985	Capital Costs	170,000	Refurbish GF #3 supply.
1985	O&M Storage	20,000	Maintain RRN low head dam
1990	Capital Costs	2,510,000	Replace RRN low head dam.
		80,000	Refurbish GF #1 supply
		6,300,000	Refurbish existing 12 mgd treatment plant
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030
2005	O&M Supply	30,000	Existing 7.1 mgd and new 2.3 mgd flow
2005	O&M Treatment	2,240,000	Existing 7.1 mgd and new 2.3 mgd flow
2005	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value
2005	Capital Costs	944,000	Expand supply to 22 mgd (RRN and RLR)
		31,100,000	New 22 mgd treatment plant
2005	O&M Supply	26,000	For 9.4 mgd flow. Increases linearly to 2030 value
2005	O&M Treatment	1,970,000	For 9.4 mgd flow. Increases linearly to 2030 value
2030	O&M Supply	34,000	For 12.6 mgd flow.
2030	O&M Treatment	3,480,000	For 12.6 mgd flow.
2030	Salvage	1,050,000	RRN low head dam and land.
East Grand Forks			
1980	O&M Supply	4,000	For existing 1.4 mgd flow. Increases linearly to 2005 value
1980	O&M Treatment	409,000	For existing 1.4 mgd flow. Increases linearly to 2005 value
1990	Capital Costs	3,980,000	Refurbish existing 4 mgd treatment plant
2005	Capital Costs	264,000	New 7 mgd supply.
		10,900,000	New 5 mgd treatment plant
2005	O&M Supply	6,000	For 1.9 mgd flow. Increases linearly to 2030 value
2005	O&M Treatment	633,000	For 1.9 mgd flow. Increases linearly to 2030 value.
2030	O&M Supply	8,000	For 2.6 mgd flow.
2030	O&M Treatment	760,000	For 2.6 mgd flow.
2030	Salvage	103,000	Supply.
Shared Facilities			
1985	O&M Storage	20,000	Maintain RLR low head dam
1990	Capital Costs	3,140,000	Replace RLR low head dam.
1990	O&M Storage	20,000	Maintain RLR low head dam in eight 5-year intervals to 2030
2030	Salvage	627,000	RLR low head dam.
Grand Forks Air Force Base			
1980	Capital Costs	6,290,000	For supply, 15.5 miles of 15" pipe from GF to base
1980	O&M Supply	19,000	Existing 16" and new 15" pipe. Uniform to 2030
Equivalent Annual Cost		4,970,000	

Notes: (1) Components of supply are intake structures and water transmission lines
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually

TABLE 12 CON'T

ALTERNATIVE I-A-1-b PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes[1]
Grand Forks			
1980	O&M Supply	23,000	For existing 7.7 mgd flow. Uniform to 2005.
1980	O&M Treatment	1,340,000	For existing 7.7 mgd flow. Uniform to 2005.
1985	Capital Cost	170,000	Refurbish GF #3 supply.
1990	Capital Cost	80,000	Refurbish GF #1 supply.
		4,970,000	Refurbish existing 12 mgd treatment plant.
2005	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value.
East Grand Forks			
1980	O&M Supply	5,000	For existing 1.5 mgd flow. Increases linearly to 2005 value.
1980	O&M Treatment	427,000	For existing 1.5 mgd flow. Increases linearly to 2005 value.
1990	Capital Cost	3,120,000	Refurbish existing 4 mgd treatment plant.
2005	O&M Supply	6,000	For 2.1 mgd flow.
2005	O&M Treatment	514,000	For 2.1 mgd flow.
2005	Abandon Facilities	0	Supply and existing 4 mgd treatment plant. No salvage value.
Combined Facilities			
1980	Capital Cost	9,670,000	New 6 mgd treatment plant and land.
		1,346,000	Supply for 6 mgd pumping (RRN).
1980	O&M Supply	2,000	For 0 mgd flow. Increases linearly to 2005 value.
1980	O&M Treatment	0	For 0 mgd flow. Increases linearly to 2005 value.
1980	O&M Storage	20,000	Maintain RRN low head dam.
		20,000	Maintain RLR low head dam.
1990	Capital Cost	2,510,000	Replace RRN low head dam.
		3,140,000	Replace RLR low head dam.
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030.
		20,000	Maintain RLR low head dam in eight 5-year intervals to 2030.
2005	O&M Supply	12,000	For 2.6 mgd flow.
2005	O&M Treatment	474,000	For 2.6 mgd flow.
2005	Relocation of GF/EGF Supply/Treatment to new site		
2005	Capital Cost	2,228,000	Expand supply to 30 mgd (RRN and RLR).
		31,300,000	New 30 mgd treatment plant.
2005	O&M Supply	35,000	For 12.4 mgd flow. Increases linearly to 2030 value.
2005	O&M Treatment	3,150,000	For 12.4 mgd flow. Increases linearly to 2030 value.
2030	O&M Supply	45,000	For 16.7 mgd flow.
2030	O&M Treatment	2,800,000	For 16.7 mgd flow.
2030	Salvage	2,290,000	Low head dams, supply, land.
Grand Forks Air Force Base			
1980	Capital Cost	6,290,000	For supply, 15.5 miles of 15" pipe from GF to base.
1980	O&M Supply	19,000	Existing 16" and new 15" pipe Uniform to 2030
Equivalent Annual Cost		6,400,000	

Notes: (1) Components of supply are intake structures and water transmission lines.
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually.

ALTERNATIVE I-A-2-b PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes[1]
Grand Forks			
1980	O&M Supply	22,000	For existing 7.1 mgd flow. Uniform to 2005
1980	O&M Treatment	1,280,000	For existing 7.1 mgd flow. Uniform to 2005
1985	Capital Costs	170,000	Refurbish GF #3 supply
1990	Capital Costs	80,000	Refurbish GF #1 supply
		5,050,000	Refurbish existing 12 mgd treatment plant
2005	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value
East Grand Forks			
1980	O&M Supply	4,000	For existing 1.4 mgd flow. Increases linearly to 2005 value
1980	O&M Treatment	409,000	For existing 1.4 mgd flow. Increases linearly to 2005 value
1990	Capital Costs	3,000,000	Refurbish existing 4 mgd treatment plant
2005	O&M Supply	6,000	For 1.9 mgd flow
2005	O&M Treatment	485,000	For 1.9 mgd flow
2005	Abandon Facilities	0	Supply and existing 4 mgd treatment plant. No salvage value
Combined Facilities			
1980	Capital Costs	7,650,000	New 4 mgd treatment plant and land
		1,552,000	Supply for 4 mgd pumping (RRN)
1980	O&M Supply	2,000	For 0 mgd flow. Increases linearly to 2005 value
1980	O&M Treatment	0	For 0 mgd flow. Increases linearly to 2005 value
1985	O&M Storage	20,000	Maintain RRN low head dam.
		20,000	Maintain RLR low head dam
1990	Capital Costs	2,510,000	Replace RRN low head dam
		3,140,000	Replace RLR low head dam
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030
		20,000	Maintain RLR low head dam in eight 5-year intervals to 2030
2005	O&M Supply	9,000	For 2.3 mgd flow
2005	O&M Treatment	584,000	For 2.3 mgd flow
2005	Relocation of GF/EGF Supply/Treatment to New Site		
2005	Capital Cost	2,024,000	Expand supply to 26 mgd (RRN and RLR)
		27,800,000	New 26 mgd treatment plant
2005	O&M Supply	32,000	For 11.3 mgd flow. Increases linearly to 2030 value
2005	O&M Treatment	2,000,000	For 11.3 mgd flow. Increases linearly to 2030 value
2030	O&M Supply	42,000	For 15.2 mgd flow
2030	O&M Treatment	2,550,000	For 15.2 mgd flow
2030	Salvage	2,130,000	Low head dams, supply, land
Grand Forks Air Force Base			
1980	Capital Costs	6,290,000	For supply, 15.5 miles of 15" pipe from GF to base
1980	O&M Supply	19,000	Existing 16" and new 15" pipe. Uniform to 2030
Equivalent Annual Cost		6,070,000	

Notes: (1) Components of supply are intake structures and water transmission lines
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually

ALTERNATIVE I-B-1-b PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes[1]
Grand Forks			
1980	O&M Supply	23,000	For existing 7.7 mgd flow. Uniform to 2005
1980	O&M Treatment	1,560,000	For existing 7.7 mgd flow. Uniform to 2005
1985	Capital Costs	170,000	Refurbish GF #3 supply.
1990	Capital Costs	80,000	Refurbish GF #1 supply.
		6,510,000	Refurbish existing 12 mgd treatment plant
2005	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value
East Grand Forks			
1980	O&M Supply	5,000	For existing 1.5 mgd flow. Increases linearly to 2005 value
1980	O&M Treatment	364,000	For existing 1.5 mgd flow. Increases linearly to 2005 value.
1990	Capital Costs	1,990,000	Refurbish existing 4 mgd treatment plant
2005	O&M Supply	6,000	For 2.1 mgd flow
2005	O&M Treatment	663,000	For 2.1 mgd flow
2005	Abandon Facilities	0	Supply and existing 4 mgd treatment plant. No salvage value.
Combined Facilities			
1980	Capital Costs	12,700,000	New 6 mgd treatment plant and land.
		1,369,000	Supply for 6 mgd pumping (RRN).
1980	O&M Supply	2,000	For 0 mgd flow. Increases linearly to 2005 value.
1980	O&M Treatment	0	For 0 mgd flow. Increases linearly to 2005 value.
1985	O&M Storage	20,000	Maintain RRN low head dam.
		20,000	Maintain RLR low head dam.
1990	Capital Costs	2,510,000	Replace RRN low head dam
		3,140,000	Replace RLR low head dam
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030
		20,000	Maintain RLR low head dam in eight 5-year intervals to 2030.
2005	O&M Supply	12,000	For 2.6 mgd flow
2005	O&M Treatment	816,000	For 2.6 mgd flow
2005	Relocation of GF/EGF Supply/Treatment to New Site		
2005	Capital Costs	2,228,000	Expand supply to 30 mgd (RRN and RLR)
		40,700,000	New 30 mgd treatment plant
2005	O&M Supply	35,000	For 12.4 mgd flow. Increases linearly to 2030 value.
2005	O&M Treatment	3,440,000	For 12.4 mgd flow. Increases linearly to 2030 value
2030	O&M Supply	45,000	For 16.7 mgd flow
2030	O&M Treatment	3,140,000	For 16.7 mgd flow
2030	Salvage	2,290,000	Low head dams, supply, land
Grand Forks Air Force Base			
1980	Capital Costs	6,290,000	For supply, 15.5 miles of 15" pipe from GF to base.
1980	O&M Supply	19,000	Existing 16" and new 15" pipe. Uniform to 2030.
Equivalent Annual Cost		5,210,000	

Notes: (1) Components of supply are intake structures and water transmission lines
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually

ALTERNATIVE I-B-2-b PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes[1]
Grand Forks			
1980	O&M Supply	22,000	For existing 7.1 mgd flow. Uniform to 2005
1980	O&M Treatment	1,480,000	For existing 7.1 mgd flow. Uniform to 2005
1985	Capital Costs	170,000	Refurbish GF #3 supply
1990	Capital Costs	80,000	Refurbish GF #1 supply.
		6,300,000	Refurbish existing 12 mgd treatment plant
2005	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value
East Grand Forks			
1980	O&M Supply	4,000	For existing 1.4 mgd flow. Increases linearly to 2005 value
1980	O&M Treatment	557,000	For existing 1.4 mgd flow. Increases linearly to 2005 value
1990	Capital Costs	3,980,000	Refurbish existing 4 mgd treatment plant
2005	O&M Supply	6,000	For 1.9 mgd flow.
2005	O&M Treatment	635,000	For 1.9 mgd flow.
2005	Abandon Facilities	0	Supply and existing 4 mgd treatment plant. No salvage value
Combined Facilities			
1980	Capital Cost	10,000,000	New 4 mgd treatment plant and land
		1,552,000	Supply for 4 mgd pumping (RRN)
1980	O&M Supply	2,000	For 0 mgd flow. Increases linearly to 2005 value
1980	O&M Treatment	0	For 0 mgd flow. Increases linearly to 2005 value
1985	O&M Storage	20,000	Maintain RRN low head dam.
		20,000	Maintain RLR low head dam.
1990	Capital Costs	2,510,000	Replace RRN low head dam.
		3,140,000	Replace RLR low head dam.
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030
		20,000	Maintain RLR low head dam in eight 5-year intervals to 2030
2005	O&M Supply	9,000	For 2.3 mgd flow.
2005	O&M Treatment	760,000	For 2.3 mgd flow.
2005	Relocation of GF/EGF Supply/Treatment to New Site		
2005	Capital Costs	2,024,000	Expand supply to 26 mgd (RRN and RLR).
		35,900,000	New 26 mgd treatment plant.
2005	O&M Supply	32,000	For 11.3 mgd flow. Increases linearly to 2030 value
2005	O&M Treatment	3,270,000	For 11.3 mgd flow. Increases linearly to 2030 value
2030	O&M Supply	42,000	For 15.2 mgd flow.
2030	O&M Treatment	3,890,000	For 15.2 mgd flow
2030	Salvage	2,130,000	Low head dams, supply, land
Grand Forks Air Force Base			
1980	Capital Costs	6,290,000	For supply, 15.5 miles of 15" pipe from GF to base
1980	O&M Supply	19,000	Existing 16" and new 15" pipe. Uniform to 2030
Equivalent Annual Cost		6,820,000	

Notes: (1) Components of supply are intake structures and water transmission lines
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually

TABLE 12 CON'T

ALTERNATIVE I-A-1-c PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes[1]
Grand Forks			
1980	O&M Supply	23,000	For existing 7.7 mgd flow. Uniform to 1990.
1980	O&M Treatment	1,360,000	For existing 7.7 mgd flow. Uniform to 1990.
1985	Capital Cost	170,000	Refurbish GF #3 supply.
1990	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value.
East Grand Forks			
1980	O&M Supply	5,000	For existing 1.5 mgd flow. Increases linearly to 1990 value.
1980	O&M Treatment	427,000	For existing 1.5 mgd flow. Increases linearly to 1990 value.
1990	O&M Supply	6,000	For 1.7 mgd flow.
1990	O&M Treatment	459,000	For 1.7 mgd flow.
1990	Abandon Facilities	0	Supply and existing 4 mgd treatment plant. No salvage value.
Combined Facilities			
1980	Capital Cost	9,670,000	New 6 mgd treatment plant and land.
		1,380,000	Supply for 6 mgd pumping (RRN).
1980	O&M Supply	2,000	For 0 mgd flow. Increases linearly to 1990 value.
1980	O&M Treatment	0	For 0 mgd flow. Increases linearly to 1990 value.
1985	O&M Storage	20,000	Maintain RRN low head dam.
		20,000	Maintain RLR low head dam.
1990	O&M Supply	5,000	For 1.0 mgd flow.
1990	O&M Treatment	270,000	For 1.0 mgd flow.
1990	Capital Cost	2,510,000	Replace RRN low head dam.
		3,140,000	Replace RLR low head dam.
		2,240,000	Expand supply to 30 mgd (RRN and RLR).
		26,000,000	Replace GF/EGF treatment plants.
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030.
		20,000	Maintain RLR low head dam in eight 5-year intervals to 2030
1990	O&M Supply	30,000	For 10.3 mgd flow. Increases linearly to 2030 value.
1990	O&M Treatment	1,840,000	For 10.3 mgd flow. Increases linearly to 2015 value.
2005	Capital Cost	3,620,000	Refurbish original 6 mgd treatment cell.
2015	Capital Cost	33,700,00	Replace all treatment to 33 mgd capacity
2015	O&M Treatment	2,400,000	For 16 mgd flow. Increases linearly to 2030 value.
2030	O&M Supply	45,000	For 16.7 mgd flow.
2030	O&M Treatment	1,800,000	For 16.7 mgd flow.
2030	Salvage	15,000,000	Low head dams, supply, treatment, land
Grand Forks Air Force Base			
1980	Capital Cost	6,390,000	For supply 15.5 miles of 15" pipe from GF to base.
1980	O&M Supply	19,000	For supply existing 16" and new 15" pipe. Uniform to 2030.
Equivalent Annual Cost		4,830,000	

Notes: (1) Components of supply are intake structures and water transmission lines.
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually.

ALTERNATIVE I-A-2-c PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes[1]
Grand Forks			
1980	O&M Supply	22,000	For existing 7.1 mgd flow. Uniform to 1990
1980	O&M Treatment	1,280,000	For existing 7.1 mgd flow. Uniform to 1990
1985	Capital Costs	170,000	Refurbish GF #3 supply.
1990	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value
East Grand Forks			
1980	O&M Supply	6,000	For existing 1.4 mgd flow. Increases linearly to 1990 value
1980	O&M Treatment	408,000	For existing 1.4 mgd flow. Increases linearly to 1990 value
1990	O&M Supply	6,000	For 1.6 mgd flow
1990	O&M Treatment	444,000	For 1.6 mgd flow
1990	Abandon Facilities	0	Supply and existing 4 mgd treatment plant. No salvage value
Combined Facilities			
1980	Capital Costs	7,650,000	New 4 mgd treatment plant and land
		1,552,000	Supply for 4 mgd pumping (RRN).
1980	O&M Supply	2,000	For 0 mgd flow. Increases linearly to 1990 value
1980	O&M Treatment	0	For 0 mgd flow. Increases linearly to 1990 value
1985	O&M Storage	20,000	Maintain RRN low head dam.
		20,000	Maintain RLR low head dam.
1990	O&M Supply	4,000	For 0.8 mgd flow.
1990	O&M Treatment	350,000	For 0.8 mgd flow.
1990	Capital Costs	2,310,000	Replace RRN low head dam.
		3,130,000	Replace RLR low head dam.
		2,024,000	Expand supply to 26 mgd (RRN and RLR)
		20,700,000	Replace GF/EGF treatment plants. Capacity 18 mgd
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030
		20,000	Maintain RLR low head dam in eight 5-year intervals to 2030
1990	O&M Supply	36,000	For 9.5 mgd flow. Increases linearly to 2030 value
1990	O&M Treatment	1,730,000	For 9.5 mgd flow. Increases linearly to 2015 value
2005	Capital Costs	3,610,000	Refurbish original 4 mgd treatment cell.
2015	Capital Costs	29,300,000	Replace all treatment to 28 mgd capacity
2015	O&M Treatment	2,270,000	For 12.7 mgd flow. Increases linearly to 2030 value
2030	O&M Supply	42,000	For 15.2 mgd flow.
2030	O&M Treatment	2,550,000	For 15.2 mgd flow.
2030	Salvage	13,350,000	Low head dams, supply, treatment, land
Grand Forks Air Force Base			
1980	Capital Costs	6,290,000	For supply 15.5 miles of 15" pipe from GF to base
1980	O&M Supply	19,000	For supply existing 16" and new 15" pipe. Uniform to 2030
Equivalent Annual Cost		4,330,000	

Notes: (1) Components of supply are intake structures and water transmission lines.
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually

ALTERNATIVE I-B-1-c PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes[1]
Grand Forks			
1980	O&M Supply	23,000	For existing 7.7 mgd flow. Uniform to 1990.
1980	O&M Treatment	1,560,000	For existing 7.7 mgd flow. Uniform to 1990.
1985	Capital Costs	170,000	Refurbish GF #3 supply.
1990	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value.
East Grand Forks			
1980	O&M Supply	5,000	For existing 1.5 mgd flow. Increases linearly to 1990 value.
1980	O&M Treatment	564,000	For existing 1.5 mgd flow. Increases linearly to 1990 value.
1990	O&M Supply	6,000	For 1.7 mgd flow.
1990	O&M Treatment	603,000	For 1.7 mgd flow.
1990	Abandon Facilities	0	Supply and existing 4 mgd treatment plant. No salvage value.
Combined Facilities			
1980	Capital Costs	12,700,000	New 6 mgd treatment plant and land.
		1,580,000	Supply for 6 mgd pumping (RRN).
1980	O&M Supply	2,000	For 0 mgd flow. Increases linearly to 1990 value.
1980	O&M Treatment	0	For 0 mgd flow. Increases linearly to 1990 value.
1985	O&M Storage	20,000	Maintain RRN low head dam.
		20,000	Maintain RLR low head dam.
1990	O&M Supply	5,000	For 1.0 mgd flow.
1990	O&M Treatment	326,000	For 1.0 mgd flow.
1990	Capital Costs	2,510,000	Replace RRN low head dam.
		3,140,000	Replace RLR low head dam.
		2,240,000	Expand supply to 30 mgd (RRN and RLR).
		33,700,000	Replace GF/EGF treatment plants. Capacity 18 mgd.
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030.
		20,000	Maintain RLR low head dam in eight 5-year intervals to 2030.
1990	O&M Supply	30,000	For 10.3 mgd flow. Increases linearly to 2030 value.
1990	O&M Treatment	2,110,000	For 10.3 mgd flow. Increases linearly to 2015 value.
2005	Capital Costs	4,700,000	Refurbish original 6 mgd treatment cell.
2015	Capital Costs	44,000,000	Replace all treatment to 33 mgd capacity.
2015	O&M Treatment	2,710,000	For 16 mgd flow. Increases linearly to 2030 value.
2030	O&M Supply	45,000	For 16.7 mgd flow.
2030	O&M Treatment	3,140,000	For 16.7 mgd flow.
2030	Salvage	19,100,000	Low head dams, supply, treatment, land.
Grand Forks Air Force Base			
1980	Capital Costs	6,290,000	For supply, 15.5 miles of 15" pipe from GF to base.
1980	O&M Supply	19,000	For supply existing 16" and new 15" pipe. Uniform to 2030.
Equivalent Annual Cost		5,020,000	

Notes: (1) Components of supply are intake structures and water transmission lines.
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually.

ALTERNATIVE I-B-2-c PROPOSED IMPROVEMENTS AND COSTS

Year	Item	Cost ($)	Notes[1]
Grand Forks			
1980	O&M Supply	22,000	For existing 7.1 mgd flow. Uniform to 1990
1980	O&M Treatment	1,680,000	For existing 7.1 mgd flow. Uniform to 1990.
1985	Capital Costs	170,000	Refurbish GF #3 supply.
1990	Abandon Facilities	0	GF #1, 2, and 3 supply and existing 12 mgd treatment plant. No salvage value
East Grand Forks			
1980	O&M Supply	6,000	For existing 1.4 mgd flow. Increases linearly to 1990 value
1980	O&M Treatment	557,000	For existing 1.4 mgd flow. Increases linearly to 1990 value
1990	O&M Supply	6,000	For 1.6 mgd flow
1990	O&M Treatment	590,000	For 1.6 mgd flow.
1990	Abandon Facilities	0	Supply and existing 4 mgd treatment plant. No salvage value.
Combined Facilities			
1980	Capital Costs	10,000,000	New 4 mgd treatment plant and land.
		1,552,000	Supply for 4 mgd pumping (RRN).
1980	O&M Supply	2,000	For 0 mgd flow. Increases linearly to 1990 value
1980	O&M Treatment	0	For 0 mgd flow. Increases linearly to 1990 value.
1985	O&M Storage	20,000	Maintain RRN low head dam.
		20,000	Maintain RLR low head dam.
1990	O&M Supply	4,000	For 0.8 mgd flow
1990	O&M Treatment	415,000	For 0.8 mgd flow.
1990	Capital Costs	2,510,000	Replace RRN low head dam
		3,130,000	Replace RLR low head dam.
		2,024,000	Expand supply to 26 mgd (RRN and RLR).
		26,900,000	Replace GF/EGF treatment plants. Capacity 18 mgd
1990	O&M Storage	20,000	Maintain RRN low head dam in eight 5-year intervals to 2030
		20,000	Maintain RLR low head dam in eight 5-year intervals to 2030
1990	O&M Supply	36,000	For 9.5 mgd flow. Increases linearly to 2030 value.
1990	O&M Treatment	1,980,000	For 9.5 mgd flow. Increases linearly to 2015 value
2005	Capital Costs	4,730,000	Refurbish original 4 mgd treatment cell.
2015	Capital Costs	37,900,000	Replace all treatment to 28 mgd capacity
2015	O&M Treatment	2,500,000	For 12.7 mgd flow. Increases linearly to 2030 value
2030	O&M Supply	48,000	For 15.2 mgd flow.
2030	O&M Treatment	2,890,000	For 15.2 mgd flow.
2030	Salvage	16,700,000	Low head dams, supply, treatment, land
Grand Forks Air Force Base			
1980	Capital Costs	6,290,000	For supply, 15.5 miles of 15" pipe from GF to base
1980	O&M Supply	19,000	For supply existing 16" and new 15" pipe. Uniform to 2030
Equivalent Annual Cost		5,100,000	

Notes: (1) Components of supply are intake structures and water transmission lines
RRN - Red River of the North
RLR - Red Lake River
Unless otherwise stated, O&M costs are assumed to be applied annually

IMPACT ASSESSMENT

This section summarizes the environmental, social, and economic impacts associated with each alternative. The impact assessments are summarized in matrix form. First, water supply and treatment design condition alternatives are considered. Second, separate and combined water supply and treatment system alternatives are assessed. Table 13 presents two impact analysis matrices. The first is for three water supply and treatment design condition alternatives:

1. No action. Interim primary drinking water standards must be met with this alternative; no water conservation practices are included.

2. Proposed advanced drinking water standards must be satisfied with this alternative; no water conservation practices are included.

3. Interim primary or proposed advanced standards plus water conservation practices.

The other matrix is for the "no action" versus separate versus combined water supply and treatment alternatives.

TABLE 13

IMPACT ASSESSMENT OF WATER SYSTEM DESIGN CONDITION ALTERNATIVES

Impact	No Action (1)	Advanced Standards	With Conservation
Environmental			
Land	No effect.	Minimal.	Minimal.
Man-made Resources	No effect.	No effect.	No effect.
Natural Resources	No effect.	Increased chemical & energy requirements.	Decreased consumption use will increase streamflow. Decreased chemical and energy requirements for treatment.
Water Quality	No effect.	No effect.	Enhanced during low flow.
Air Quality	No effect.	No effect.	No effect.
Wildlife	No effect.	No effect.	No effect.
Hydrologic	No effect.	No effect.	Increased streamflow.
Public Health	Higher potential for problems.	Greater protection.	No effect.
Social			
Noise	No effect.	No effect.	No effect.
Displacement of People	No effect.	No effect.	No effect.
Aesthetics	No effect.	No effect.	Decreased due to changed habits.
Community Cohesion	No effect.	No effect.	May change.
Community Growth	No effect.	No effect.	Minimal effect.
Historical & Archaeological	No effect.	No effect.	No effect.
Transportation	No effect.	No effect.	No effect.
Institutional Relationships	No effect.	No effect.	No effect.
Public Acceptance	No change.	Decreased.	Decreased.
Economic			
Property Values	No effect.	No effect.	No effect.
Tax Revenues	No effect.	No effect.	No effect.
Public Facilities & Services	No effect.	No effect.	No effect.
Business & Industrial Activities	No effect.	May be impaired.	May be impaired.
Employment	No effect.	May be impaired.	May be impaired.
Agricultural Land Lost	No effect.	Minimal.	No effect.
Regional Growth	Not constrained.	May be impaired.	May be impaired.

Notes: (1) Includes the design conditions of Interim Primary Drinking Water standards and without water conservation practices.

IMPACT ASSESSMENT OF SEPARATE AND COMBINED SYSTEM ALTERNATIVES

Impact	No Action (1)	Separate Systems	Combined System
Environmental			
Land	No effect.	Will affect about 20 acres of prime agricultural land for new treatment plants.	Will affect about 15 acres of prime agricultural land for new treatment plant.
Man-made Resources	No effect.	No effect.	No effect.
Natural Resources	No effect.	Additional consumptive use; possible adverse effect at low flow; additional chemicals required for treatment.	Additional consumptive use; possible adverse effect at low flow; additional chemicals required for treatment.
Water Quality	No effect.	Possible adverse effect at low flow.	Possible adverse effect at low flow.
Air Quality	No effect.	During construction.	During construction.
Wildlife	No effect.	No effect.	No effect.
Hydrologic	No effect.	Increased consumption use reduces river flow.	Increased consumption use reduces river flow.
Social			
Noise	No effect.	During construction.	During construction.
Displacement of People	No effect.	No effect.	No effect.
Aesthetics	No effect.	May decrease locally due to large building.	May decrease locally due to large building.
Community Cohesion	May be impaired.	No change.	May change.
Community Growth	Impaired.	No constraint.	No constraint.
Historical & Archaeological	No effect.	No known effect.	No known effect.
Transportation	No effect.	During construction.	During construction.
Institutional Relationships	No effect.	No effect.	Will change.
Economic			
Property Values	May be impaired.	No change.	No change.
Tax Revenue	May be impaired.	May increase.	May increase.
Public Facilities & Services	Impaired.	May enhance.	May enhance.
Business & Industrial Activities	Constrained.	No constraint.	No constraint.
Employment	May not increase.	No constraint.	No constraint.
Agricultural Land Lost	No effect.	About 20 acres of prime agricultural.	About 15 acres of prime agricultural.
Regional Growth	Constrained.	No constraint.	No constraint.

Notes: (1) Includes continued use of existing systems, but no expansions for existing water supply and treatment systems.

EVALUATION

Planning Objective Fulfillment

The objective of the water supply study is to develop a plan for providing an adequate quantity and quality water supply to the urban area. The plan should be cost effective while recognizing social, environmental, technical, political, and institutional concerns. All of the comprehensive alternatives meet the planning objective of providing an adequate quantity of water. The "no action" alternative would not meet the planning objective because water supply would fall short of demand.

Economics and National Economic Development

Table 14 summarizes the equivalent annual cost of the water supply and treatment alternatives considered. This table indicates that the most economical alternative is for Grand Forks and East Grand Forks to develop a combined water supply and treatment system serving both cities in year 2005 regardless of what water quality standards apply or whether water conservation resources are implemented. As might be expected, it would be less expensive to satisfy just the interim primary drinking water standards; however, if the proposed advanced standards are promulgated and if monitoring discloses unacceptable levels of organic contaminants, then advanced treatment and its higher costs are necessary. Water conservation, of course, reduces both capital and operating costs, hence the equivalent annual costs as shown in table 14. However, the costs for residents and businesses to adopt conservation measures are not factored into the costs shown. Therefore, the "with conservation" costs shown are not directly comparable to the "without conservation" costs.

Table 14 - Equivalent annual cost summary

	I Surface water	II Garrison Diversion	III Groundwater
A. <u>Interim primary drinking water standards</u>		Supplemental flow augmentation is not required.	This source is not feasible due to inadequate recharge to the Elk Valley and/or Beach Ridge aquifers.
1. Without water conservation practices			
a. Separate supply and treatment	$4,460,000		
b. Combined supply and treatment in year 2005	4,440,000		
c. Combined supply and treatment in year 1990	4,830,000		
2. With water conservation practices			
a. Separate supply and treatment	4,170,000		
b. Combined supply and treatment in year 2005	4,070,000		
c. Combined supply and treatment in year 1990	4,330,000		
B. <u>Proposed advanced drinking water standards</u>			
1. Without water conservation practices			
a. Separate supply and treatment	5,320,000		
b. Combined supply and treatment in year 2005	5,210,000		
c. Combined supply and treatment in year 1990	5,820,000		
a. With water conservation practices			
a. Separate supply and treatment	4,970,000		
b. Combined supply and treatment in year 2005	4,820,000		
c. Combined supply and treatment in year 1990	5,100,000		

Source: Stanley Consultants, Inc.

National economic development benefits from an adequate quantity and quality of water include potential increased output of goods and services on the local, regional, State, and national levels. Without additional water supply and treatment facilities, the economic development accounts would be adversely affected, and business and industrial activities, employment, and regional growth may be impaired.

Environmental Quality

The environmental quality of the area is not affected greatly by either the "no action" alternative or proposed improvement plans. The proposed improvements allow further reduction of streamflow which may adversely affect downstream water quality and uses during low flows. Additional natural resources will be consumed, including water, chemicals, and energy; 10 to 15 acres of prime agricultural land will be removed from production. Environmental impacts during construction would be localized and temporary.

Regional Development

Adequate water supplies are essential for continued regional development and will attract more industrial, employment, and economic growth to the immediate urban area. Growth in the immediate urban area, the study area, and the region would be hindered without expanded water supply and treatment facilities.

Social Well-Being

Sufficient quantities of potable water are essential for maintaining the social well-being of residents by enhancing prospects for future business, industrial, and employment growth. During construction activities, temporary adverse impacts include equipment noise, dust, and traffic congestion. The new water treatment plant building might reduce the aesthetic appeal and suitability for residential development of adjacent lands.

Institutional

Continued use of separate water supply and treatment systems will not change existing institutional and management relationships. Combined water systems would require changes in existing institutional arrangements. A formal agreement would specify arrangements for making decisions, financing, and managing the system.

Selected Plan

Selection of the alternative to be implemented will be based on local reviews and inputs. Based on the economic analysis, the selected plan would be either alternative I-A-1-b, I-A-2-b, I-B-1-b, or I-B-2-b. These alternatives have in common the use of the Red River of the North and Red Lake River as the raw water source and combining the cities' water treatment and supply facilities in year 2005. Each alternative involves a different combination of water quality standards and water conservation practices.

DROUGHT EMERGENCY PLAN OF ACTION

General

The low-flow analyses conducted as part of the water supply study indicated that the Red River of the North and Red Lake River, supplemented by existing in-channel storage provided by low head dams, can meet the urban area's year 2030 projected water needs during the design 50-year drought event. Indeed, if East Grand Forks had a raw water intake in the Red River of the North pool, both cities could weather a 100-year drought. However, there is still serious local concern over droughts of possibly even greater severity. Therefore, the Corps had a drought emergency plan of action prepared. This plan could be implemented when available sources of water supply can no longer satisfy local needs. The plan includes:

- A step-by-step procedure to be implemented as available water supplies dwindle.

- A review of governmental agencies which provide assistance during droughts.

There are no alternative surface water sources that could be used as raw drinking water sources during drought emergencies. There are no nearby lakes or reservoirs; and during drought conditions, coulees, oxbows, and other depressions would be dry. The wastewater treatment lagoons might be a source of nonpotable water (such as for irrigation); but according to the Minnesota Department of Health, wastewater reuse as a source for potable water is not an acceptable alternative at this time.

The availability and acceptability of groundwater sources are limited. Groundwater which accumulates in rock quarries and other excavations could be a source of nonpotable water, say for livestock and irrigation. The Grand Forks aquifer located below the city has poor water quality which would not be potable without extensive treatment. The Elk Valley aquifer and the Beach Ridge aquifers are potential sources of relatively good quality water. However, the large number of wells and long distances from the urban area would make these waters expensive. During severe and extreme drought conditions, water from the Elk Valley aquifer would probably be trucked to the urban area.

With only limited potential for alternative sources of supplemental water supply, water conservation becomes a vital part of the drought emergency plan of action. Conservation during nondrought periods was discussed earlier; reductions in total water use of as much as 10 to 15 percent are shown in table 15. Much greater savings can be achieved during severe droughts as the public responds to the emergency. These emergency measures can carry over into postdrought savings from retrofitted devices and greater public and business awareness of water conservation.

Table 15 - Estimated water savings by various water conservation programs

Program	Estimated savings (percent)
Public education including bill inserts, newsletters, pamphlets, workshops, and media announcements	1 1/2 to 5
Public education and installation of water saving devices (retrofit)	4 to 7 1/2
Public education, retrofit, and a rate change including a surcharge for excess use	8
Public education, mandatory retrofit, plumbing code change, lawn irrigation ordinance, and modified rate structure with excess use surcharge	10 to 15

Local governments have ultimate responsibility for implementing the drought emergency plan of action. The drought action team which assesses the situation, makes recommendations, and implements local efforts might include the city council, water utility personnel, director of public works, city engineer, chamber of commerce, and other interested groups. Emergency services agencies at local, regional, State, and Federal levels can assist local governments after all possible local efforts have been undertaken. The drought action plan includes two major parts:

- Water demand reduction plan
- Agency assistance and responsibilities at local, regional, State, and Federal levels

Water Demand Reduction Plan

The key o surviving a drought emergency is to reduce total water use (demand) via a plan staged to respond to increasingly severe drought conditions. The primary consideration during a drought emergency is maintenance of public health and well-being of the general populace; the basic needs of residential users have priority over commercial, industrial, and irrigation needs.

The water demand reduction plan involves five stages. The first two stages invoke basically voluntary measures to reduce the total water demand and to alert the public that drought conditions may become more severe. During more severe droughts, local governments would enforce mandatory water reduction measures provided in the last three stages. Policing of mandatory measures would be through public support, monitoring of water meters, and inspection of water-using facilities. A pricing system that penalizes excess water use should be implemented as an incentive to reduce use. The schedule for implementing this plan depends on the available quantity of water as constrained by river flow, storage volume, intake capabilities, pumping capacities, and transmission capacities.

The combined Red River of the North and Red Lake River flows and in-channel storage can satisfy urban area water demands for droughts up to at least 100-year return frequency. Therefore, the water demand reduction plan would be implemented less than once every 100 years on the average. If East Grand Forks relies only on Red Lake River flow and in-channel storage as its water source, the water demand reduction plan would have to be implemented on the average once every 50 to 60 years.

If the low-head dams would be lost and in- and/or off-channel supplemental storage would not be available, streamflows must satisfy maximum day rather than average day demands. Based on the low-flow frequency analysis, the water demand reduction plan would have to be implemented with the following frequency:

		Implemented every "x" years	
Stage	Percent water demand reduction	Based on 1980 water demands	Based on 2030 water demands
A	-	100	5
B	10	>200	6
C	30	>200	16
D	50	>200	>200
F	70	>200	>200

If East Grand Forks relies solely on Red Lake River flows, the water demand reduction plan would have to be implemented with the following frequency:

Stage	Percent water demand reduction	Implemented every "x" years: Based on 1980 water demands	Implemented every "x" years: Based on 2030 water demands
A	-	15 to 20	1 to 2
B	10	15 to 20	1 to 2
C	30	35	15 to 20
D	50	>200	20
F	70	>200	200

Clearly, maintaining and replacing the urban area's low-head dams is extremely important.

The five stages of the water demand reduction plan are briefly summarized in table 16. More details can be found in the Grand Forks East Grand Forks Urban Water Resources Study Water Supply Appendix.

Table 16 - Five-stage water demand reduction plan[1]

Stage	Estimated reduction in demand (percent)	Implementation criteria[2]: When river flow and supplemental storage cannot furnish	or	When water treatment and supply facilities cannot furnish	Steps
A	-	200 percent of demand plus 8 cfs for next 6 months		100 percent of demand	Alert public and local officials of low-flow situation; increase maintenance and monitoring of water treatment and transmission facilities and water uses.
B	≤ 10	150 percent of demand plus 8 cfs for next 3 months		90 percent of demand	A steps plus request residents to reduce consumption to 90 gcd and retrofit water-saving devices; restrict lawn watering, car washing, pool filling.
C	10-40	100 percent of demand plus 8 cfs for next 1 month		60 to 90 percent of demand	B steps plus limit residents to 75 gcd; reduce air conditioning load on buildings using cooling towers; businesses reduce water pressure and close most restrooms; eliminate most lawn watering.
D	40-60	<70 percent of demand plus 8 cfs (Note: storage would be essentially gone)		40 to 60 percent of demand	C steps plus limit residents to 40 gcd; further reduce air conditioning load; businesses serve no water, shut off sinks in public restrooms, wash linens at commercial laundry outside drought area; discontinue lawn watering and car washing.
F	>60	<50 percent of demand plus 8 cfs (Note: storage would be gone)		<40 percent of demand	D steps plus limit residents to 30 gcd; begin use of alternate potable water sources (Elk Valley aquifer, quarries); set up emergency water supply points to dispense minimum essential water needs for human consumption; use nonpotable water for toilet flushing or use other sanitary facilities, such as chemical toilets; turn off all air conditioning; businesses using water in manufacture haul from outside drought area.

(1) Details are available in Grand Forks-East Grand Forks Urban Water Resources Study Water Supply Appendix.
(2) Assumes low head dams are effective.

Agency Assistance and Responsibilities

Local, regional, State, and Federal agencies can provide assistance to the local governments in a drought emergency:

- General information such as weather forecasts, streamflow data, and reservoir operation.

- Technical and financial aid such as procedures, manpower, supplies, equipment, and funds.

As water supplies dwindle, local governments should take the following actions:

- Monitor weather forecasts, streamflows, and reservoir operation.

- Implement the "Water Demand Reduction Plan" and commit all possible local resources including funds, manpower, and equipment.

- Contact local emergency services coordinators.

- Declare a drought emergency.

As local capabilities are exceeded, outside assistance should be obtained. Assistance should be requested when stage C of the Water Demand Reduction Plan is implemented. Requests for technical and financial aid from State and Federal agencies must be handled through the local emergency services coordinators:

- Grand Forks County Disaster Emergency Services.

- East Grand Forks and Polk County Emergency Services.

Figure 26 indicates the agency (and person, when available) that should be contacted.

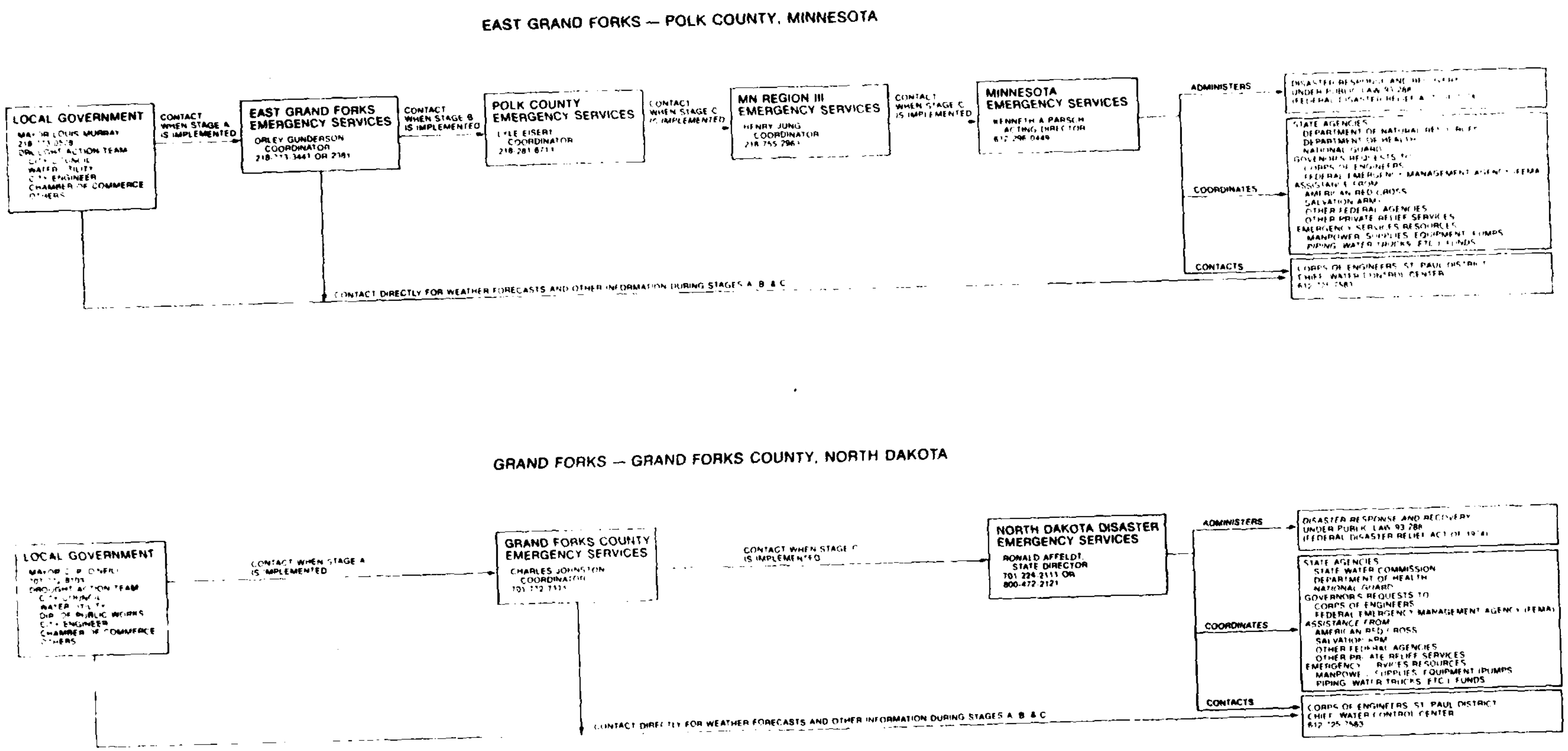


FIGURE 26
Drought Action Organization Chart

WASTEWATER

GENERAL

Pollutant sources were divided into two categories:

- Major point sources - wastewater treatment facilities.

- Intermittent point and nonpoint sources - storm sewers, combined sewers, overland urban runoff.

The stage 2 studies addressed both categories. Most questions regarding major point sources were resolved, including the most cost-effective means of providing various degrees of treatment that might be required in the future, environmental and social impacts, and implementation and management consequences. Community planning efforts seemed properly focused on effective future improvements of their facilities; it was concluded, therefore, that further studies of major point sources in stage 3 were not necessary.

The stage 2 studies of intermittent point and nonpoint sources concluded that separation of Grand Forks combined sewers was the most cost-effective structural alternative; the cost effectiveness of certain nonstructural alternatives was also favorable. It was recommended, however, that more detailed investigations be conducted in stage 3. The city of Grand Forks requested that the Environmental Protection Agency accept the stage 2 report in fulfillment of the step 1 requirements of its Construction Grants Program, a step toward Federal financial assistance for the city, which had already begun a combined sewer separation project. The Environmental Protection Agency ruled, however, that further studies be made to reaffirm the cost effectiveness of combined sewer separation using local, rather than generalized, costs. Thus, stage 3 studies focused on the combined sewer overflow problem.

The final stage 3 report was prepared in accordance with the EPA's step 1 requirements as set forth in a Memorandum of Understanding between the agency, Corps, North Dakota State Department of Health, and city of Grand Forks. The draft stage 3 report (prepared by a consulting firm under contract to the St. Paul District) was submitted to the EPA in November 1979 and was accepted by the EPA and State Department of Health. As of this writing, the city has received step 2 funds and has a consulting firm preparing plans and specifications. Available step 3 funds for construction appear adequate for about half the entire sewer separation project; prospects for additional money to finish the project are uncertain at this time because of Federal budget constraints.

PROBLEMS - ISSUES - NEEDS - CONCERNS

In stage 2, the following wastewater-related problems, issues, needs, and concerns in the study area were identified and divided into two general categories - resource water quality problems and wastewater treatment problems:

- Major surface water quality problems for the Red and Red Lake Rivers include high turbidity, high fecal coliform count, and low dissolved oxygen levels following rainfall-runoff events and during winter ice cover.

- Many physical and chemical water quality standards cannot be met in the rivers as a result of upstream point discharges, nonpoint discharges, and natural runoff water quality levels. At high river flows, water quality problems may result from nonpoint sources. At low flows, water quality problems may result from point discharges. The study area contributes point and nonpoint organic loads via combined sewer overflows, wastewater treatment plant discharges, and urban nonpoint runoff. Removing or reducing these organic loads would enhance dissolved oxygen levels

within the study area. However, since upstream point and nonpoint sources control overall water quality of the two rivers, little can be done within the study area to significantly improve their overall water quality.

- During dry weather operation, Grand Forks combined sewers carry sanitary wastes to lift stations and thence to the city's treatment facility. During rainfall- or snowmelt-runoff events, the combined sewers carry runoff as well as sanitary wastes. If these flows exceed the capacity of the combined sewer system, untreated sanitary wastes are discharged into Grand Forks water supply pool behind the low-head dam on the Red River of the North. The overloaded combined sewers can also cause backup of untreated wastes into basements hooked into the combined system. These problems pose serious public health threats.

- Quality of some groundwater sources is affected by high concentrations of wastewater from septic tanks/drainfields in soils that are not easily drained.

- Existing wastewater treatment facilities in the study area do not meet State design criteria even though effluents from the facilities meet current effluent standards:

1. Grand Forks - Facility does not meet liquid retention time or organic loading criteria. Present plans provide for expansion to meet needs through 1990.

2. East Grand Forks - Existing lagoons do not meet three-cell series design criteria. System could be organically overloaded by 1995.

3. Grand Forks Air Force Base - Existing facilities are marginally hydraulically overloaded; however, facilities are not expected to need expansion.

4. Thompson - Present facilities are organically and hydraulically overloaded, but a Section 201 Facilities Plan is being prepared to address this deficiency.

5. Manvel - The lagoon system does not meet three-cell design criteria, but appears to be adequate to meet future growth needs of this community.

6. Emerado - The city lagoons are hydraulically overloaded and do not meet the State's three-cell design criteria.

7. New subdivisions south and west of Grand Forks - These areas are served with individual septic tank/drainfield systems that have overloaded the capacity of the soil in some areas.

- Both Grand Forks and East Grand Forks have the following concerns:

1. Are there economic and management advantages to regional wastewater treatment?

2. Are there economic, social, and environmental advantages to continuing the lagoon method of treatment?

3. Are there ways to reduce odor problems from lagoons?

4. What alternative methods of wastewater treatment are viable in meeting the Public Law 92-500 1983 (best practical treatment) and 1985 (zero discharge) goals?

5. What alternative methods and growth management options are available to provide wastewater treatment for urban fringe areas?

6. What are the water quality characteristics of urban runoff from the study area? How can urban runoff loads be reduced to prevent possible water quality problems?

7. Are there advantages to using wastewater as a water supply source?

FORMULATION OF ALTERNATIVES

Stage 2's selection and screening of alternatives involved identifying myriad alternatives and reducing them to a few viable ones. Initial screening was made by determining for each alternative the economic consequences, resource commitments, and environmental impacts. The effects of point and nonpoint sources on the study area's surface water quality were estimated by mass balance and dissolved oxygen evaluations.

Major Point Source Alternatives

Major point source wastewater treatment alternatives consisted of a combination of treatment facilities and transmission lines serving one or more service areas. Facilities would be expanded at appropriate times to meet projected future increased wastewater loads.

The following types of treatment were considered:

- Biological lagoons.
- Activated sludge.
- Land treatment

Four levels of treatment were analyzed:

- Level I treatment would maintain the existing level of treatment. Treatment facilities would be increased in capacity to meet increased wastewater flows with no change in effluent quality.

- Level II treatment would be secondary treatment defined by both States as an effluent quality of 25 mg/1 BOD_5 and 30 mg/1 TSS. Disinfection might be required depending on specific water quality standards and public health needs.

• Level III treatment would be additional treatment to meet effluent criteria of 10 mg/l BOD_5 and 10 mg/l TSS. If there were dissolved oxygen problems, nitrification would be considered.

• Level IV treatment would allow for essentially no discharge of critical pollutants. The effluent limitations for this level of treatment (as developed by the Corps of Engineers) include 5 mg/l BOD_5, 5 mg/l TSS, 8 mg/l total nitrogen, 0.5 mg/l ammonia nitrogen, 4 mg/l total nitrite- and nitrate-nitrogen, 0.1 mg/l total phosphorus, and 5 mg/l dissolved oxygen. This is extremely high effluent quality and is probably the upper limit that can be achieved by existing, practical wastewater treatment technology.

The types of treatment selected to meet each level are shown on figure 27. Level IV's two activated sludge processes and subsequent clarification, denitrification, filtration, and postaeration steps constitute alternative "mechanical treatment" systems.

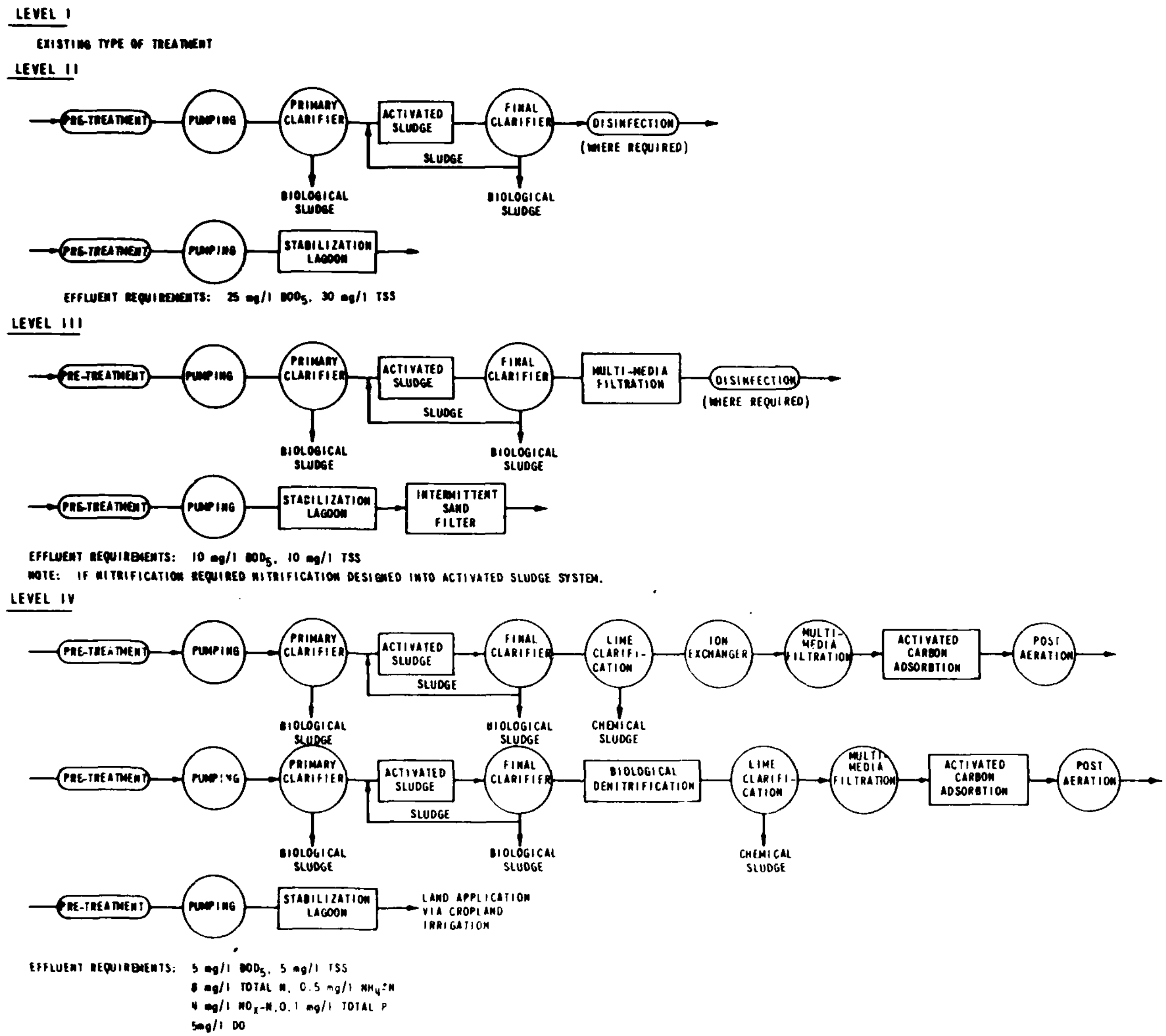


FIGURE 27 - Liquid Waste Treatment Schematics

There are nine major point sources of wastewater in the study area: American Crystal Sugar, International Co-op, Pillsbury, East Grand Forks municipal and other industrial, Grand Forks municipal and other industrial, Thompson, Manvel, Emerado, and the Grand Forks Air Force Base. Currently there are seven treatment facilities (all stabilization ponds) and two pretreatment facilities to treat these waste sources. Current plans are to expand the Grand Forks lagoons and increase industrial pretreatment and reduce water use at International Co-op. Professional judgment and knowledge of existing situations in the area were used to screen out impractical wastewater management alternatives. Assumptions included:

- Major industries in Grand Forks would continue to use the municipal treatment system.

- American Crystal Sugar would not use the East Grand Forks municipal system.

- The city of Grand Forks immediate needs for improvement include pretreatment improvements, lagoon expansion, and outfall modification.

The following structural alternatives are shown in tables 17 and 18, which identify the improvements needed and estimated costs for each level of treatment for each major discharge. Wastewater options are shown on figure 28.

Table 17 - Alternative wastewater treatment systems for major dischargers

Community/system	Treatment level I	II	III	IV
Thompson				
Separate	Existing lagoon	Lagoon, pretreatment	Lagoon, sand filter	Lagoon, land application
Regional	12-mile, 12-inch force main and 700-gpm, 150-foot head pump station			
Manvel				
Separate	Existing lagoon	Upgrade lagoon	Lagoon, sand filter	Lagoon, land application
Regional	10-mile, 4-inch force main and 150-gpm, 300-foot head pump station			
Emerado - Air Force Base				
Separate	Lagoon expansion	Lagoon expansion	Lagoon expansion, sand filter	Lagoon expansion, land application
Joint management of separate facilities	Lagoon expansion	Lagoon expansion	Lagoon expansion, sand filter	Lagoon expansion, land application
Joint facilities	Lagoon expansion	Lagoon expansion	Lagoon expansion, sand filter	Lagoon expansion, land application
	Plus 2-mile, 12-inch force main and 700-gpm, 50-foot head pump station			
Regional	12-mile, 20-inch force main and pump station			
Grand Forks-East Grand Forks-American Crystal Sugar				
Grand Forks separate	Lagoon expansion	Lagoon expansion	Lagoon expansion, sand filter	Lagoon expansion, land application
East Grand Forks separate	Lagoon expansion	Lagoon expansion	Lagoon expansion, sand filter	Lagoon expansion, land application
American Crystal Sugar separate	Lagoon expansion	Lagoon expansion	Lagoon expansion, secondary treatment, land application	Lagoon expansion, secondary treatment, land application
Grand Forks-East Grand Forks joint lagoon	Lagoon expansion	Lagoon expansion	Lagoon expansion, sand filter	Lagoon expansion, land application
	Plus 4-mile, 24-inch force main and 6,250-gpm, 50-foot head pump station			
East Grand Forks-American Crystal Sugar joint lagoon	Lagoon expansion	Lagoon expansion	Lagoon expansion, sand filter	Lagoon expansion, land application
	Plus 2-mile, 18-inch force main and 2,000-gpm, 50-foot head pump station			
Grand Forks-East Grand Forks-American Crystal Sugar joint lagoon	Lagoon expansion	Lagoon expansion	Lagoon expansion, sand filter	Lagoon expansion, land application
	Plus 2-mile, 18-inch force main and 2,000-gpm, 50-foot head pump station plus 4-mile, 30-inch force main and 7,000-gpm, 50-foot head pump station			
Grand Forks-East Grand Forks joint mechanical	None	Activated sludge	Activated sludge, filtration	Activated sludge, filtration, lime clarification and recalcination, ion exchange, activated carbon, postaeration
	Plus 5,000-foot, 36-inch force main			

Table 18 - Equivalent annual costs of wastewater treatment alternatives

Community/system	Treatment level I	II	III	IV
Thompson				
Separate	$77,000	$77,000	$88,000	$139,000
Regional	152,000 (1)	152,000 (1)	152,000 (1)	152,000 (1)
Manvel				
Separate	25,000	25,000	28,000	48,000
Regional	80,000 (1)	80,000 (1)	80,000 (1)	80,000 (1)
Emerado - Air Force Base				
Separate	171,000	171,000	218,000	424,000
Joint facilities	174,000	174,000	215,000	398,000
Joint management of separate facilities	154,000	154,000	201,000	406,000
Regional	378,000 (2)	378,000 (2)	378,000 (2)	378,000 (2)
Grand Forks-East Grand Forks-American Crystal Sugar				
Grand Forks separate lagoon	1,087,000	1,087,000	1,308,000	2,106,000
East Grand Forks separate lagoon	205,000	205,000	230,000	596,000
American Crystal Sugar separate lagoon	115,000	115,000	326,000	326,000
Total separate systems	1,407,000	1,407,000	1,914,000	3,028,000
Grand Forks-East Grand Forks joint lagoon and American Crystal Sugar separate lagoon	1,731,000	1,731,000	2,230,000	3,275,000
East Grand Forks-American Crystal Sugar joint lagoon and Grand Forks separate lagoon	1,561,000	1,561,000	1,972,000	3,340,000
Grand Forks-East Grand Forks-American Crystal Sugar joint lagoon	1,784,000	1,784,000	2,182,000	3,258,000
Grand Forks-East Grand Forks joint mechanical and American Crystal Sugar separate lagoon	-	1,828,000 (3)	2,358,000 (3)	3,828,000 (3)
Least total cost for study area	1,663,000	1,663,000	2,231,000	3,621,000

(1) Does not include cost of treatment at regional facility.
(2) Includes cost of interceptor and pumping station; does not include cost of treatment at regional facility.
(3) Does not include nitrification to mechanical plant, which would add about $134,000 in equivalent annual costs.

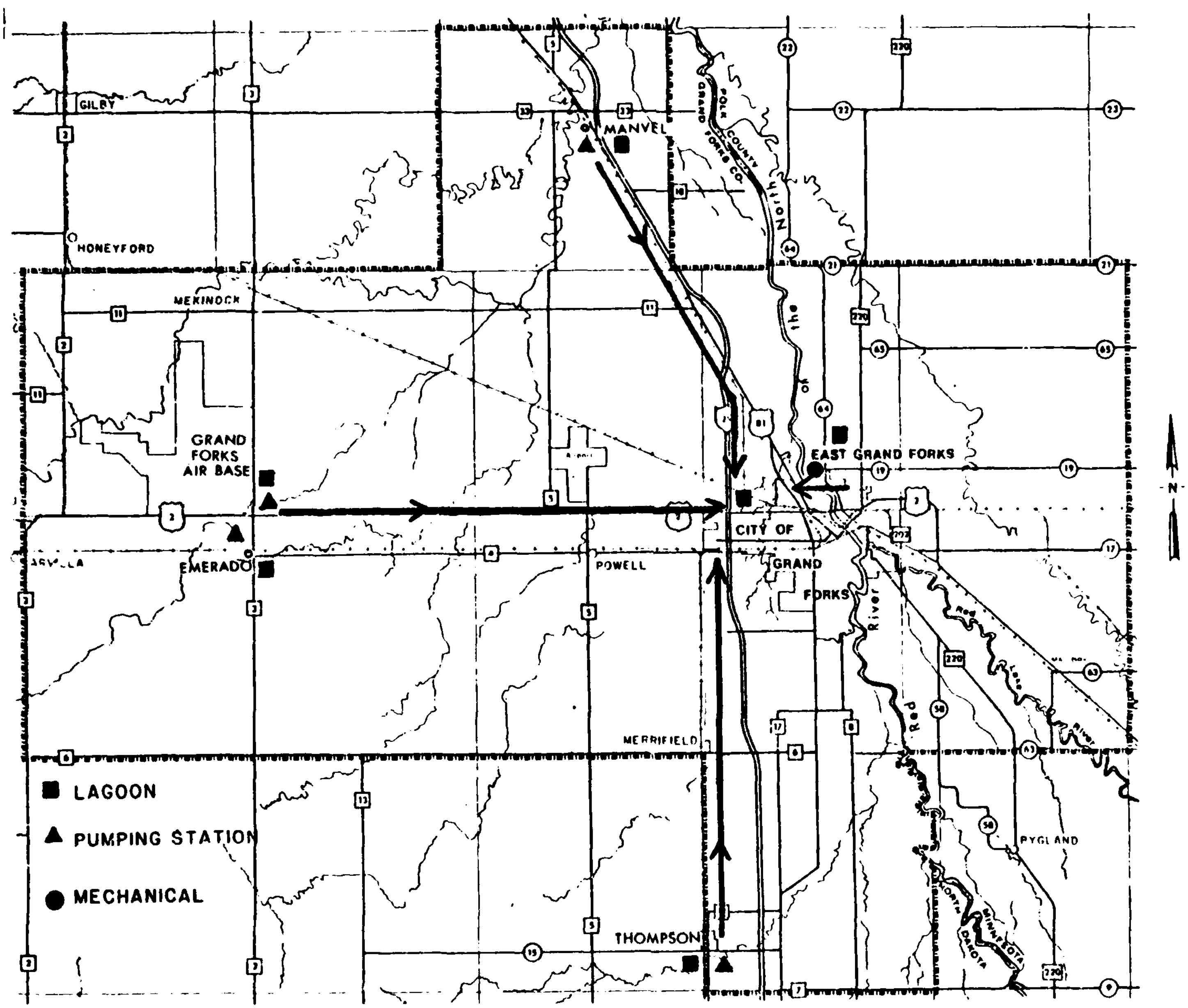


FIGURE 28 – WASTEWATER TREATMENT ALTERNATIVES

1. Thompson - Projected wastewater flows are expected to increase from 0.05 mgd at present to 0.24 mgd in 2030. Alternatives include continuing separate treatment or entering into a regional system. The regional alternative would require construction of 12 miles of 12-inch interceptor force main and a 700-gpm, 150-foot head pumping station. The average annual cost of the regional alternative is estimated at $152,000 (not including treatment costs at a regional facility), which table 18 shows is higher than for any level of treatment at a separate facility.

2. Manvel - The population and wastewater flow are expected to be stable. The community could upgrade its separate lagoon system to meet whatever level of treatment was required or join a regional facility. A regional facility would require 10 miles of 4-inch interceptor force main and a 150-gpm, 300-foot head pumping station at an estimated annual cost of $80,000, much higher than any level of treatment at a separate facility.

3. Emerado-Air Force Base - Because of the proximity of Emerado and the Grand Forks Air Force Base, four alternatives were considered: separate facilities with and without joint management, joint facilities, and regional facilities. Wastewater flows from Emerado are expected to increase from 0.09 mgd to 0.20 mgd in 2030; Air Force base wastewater flows are expected to remain constant at 1.13 mgd. Joint facilities would require 2 miles of 12-inch interceptor force main, a 700-gpm, 50-foot head pump station, and expansion of a lagoon system to meet State design criteria. Joint management of separate facilities is estimated to save only half what operating a joint facility would save, but dispenses with the need for a connecting pipeline. Connecting Emerado and the Air Force base to a regional system with Grand Forks-East Grand Forks would require 12 miles of 20-inch interceptor sewer and a pumping station. Table 18 shows estimated costs for joint management of separate facilities are less than for the separate and joint facility alternatives for treatment levels I, II, and III. Regional treatment appears to be economically competitive if level IV treatment is required, but the costs of treatment at the regional facility were not included. It should also be noted that Emerado opposes joint treatment. Therefore, in table 18, the least total cost for the study area assumes separate facilities with joint management.

4. Grand Forks-East Grand Forks-American Crystal Sugar - The preceding paragraphs show that a regional system would not be cost effective. Therefore, the alternatives considered for Grand Forks and East Grand Forks were restricted to separate lagoon systems, joint mechanical treatment for Grand Forks and East Grand Forks (American Crystal Sugar not included because lagoons are more cost effective in handling its highly seasonal flow), and joint lagoons. The separate and joint lagoon alternatives can meet treatment levels I and II, with multimedia filters added for level III and land application for level IV. Presently, 970 acres of land are used for lagoons; this figure is projected to increase to 2,300 acres by 2030. An additional 6,000 acres would be needed if land application is required. The joint mechanical alternative assumes immediate conversion to mechanical treatment using the activated sludge process. Nitrification could be added if needed to reduce effluent concentrations of ammonia.

Nonstructural alternatives such as the following were suggested to reduce major point source wastewater flow and loads.

1. Restrict use of garbage disposals and phosphate detergents.

2. Encourage water conservation by changing plumbing codes to require use of water-saving devices in new construction, metering water and charging for actual use, and retrofitting water-saving devices ranging from simple faucet aerators to recycling of wastewater in the home.

3. Reduce infiltration/inflow in collection systems.

Intermittent Point Source and Nonpoint Source Alternatives

Additional wastewater load reductions to receiving streams in the study area could be accomplished by reducing the loads from intermittent point sources such as storm sewers, combined sewers, and overland urban runoff. Approximately 8.4 square miles of developed area in Grand Forks and East Grand Forks is drained by these sources. This runoff, at times, can be as polluted as untreated municipal wastewater.

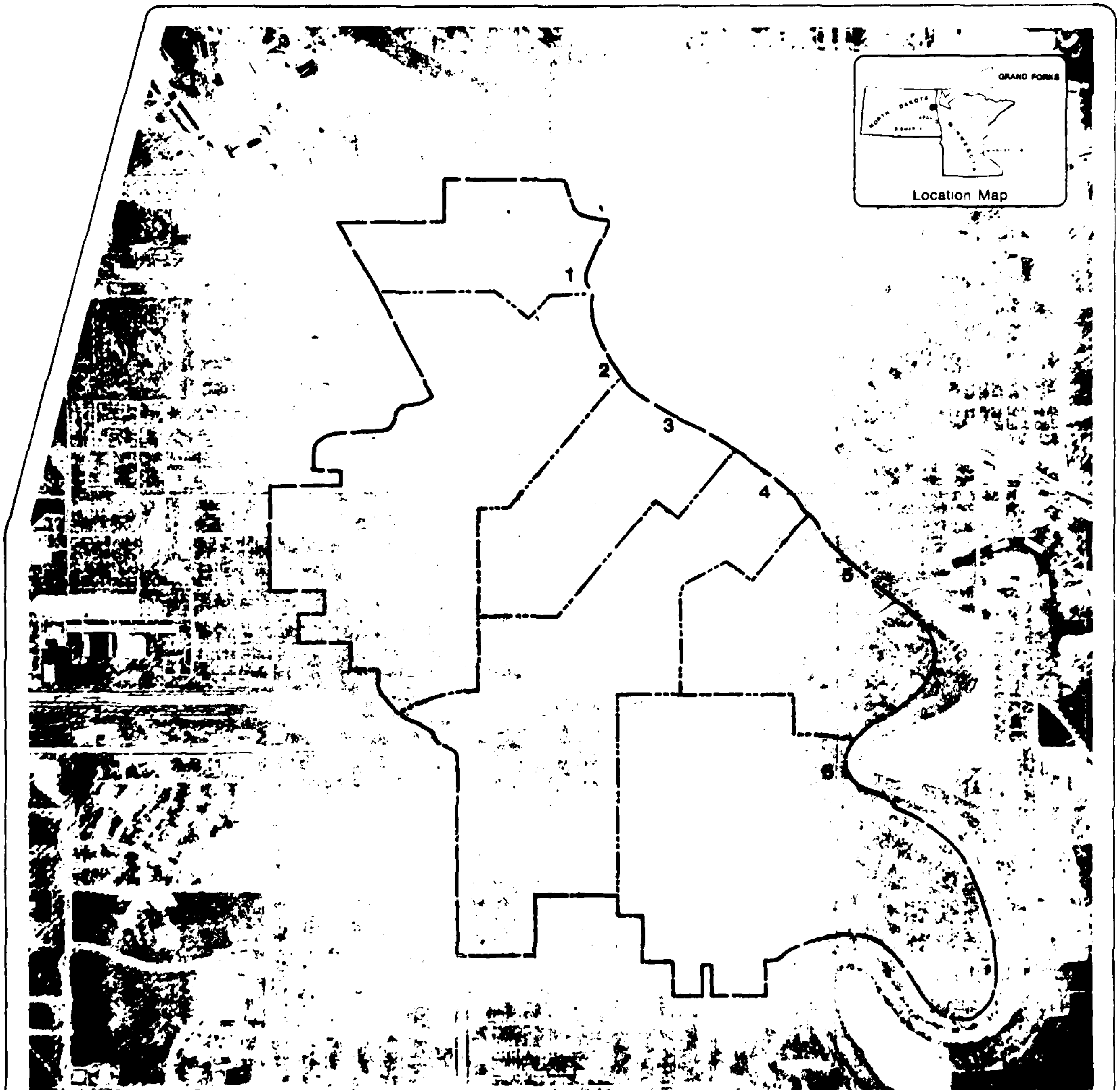
The North Dakota State Department of Health and the Environmental Protection Agency focused on Grand Forks' combined sewer overflows as the most critical problem area.

As discussed earlier, stage 2 studies included a preliminary cost and effectiveness screening of urban runoff control alternatives. The report concluded that sewer separation was the most cost-effective alternative. Grand Forks requested that the Environmental Protection Agency accept the stage 2 report as fulfilling the Construction Grants Program step 1 requirements. The agency, however, required additional economic evaluations relative to other alternatives using up-to-date, local cost data. These follow-up studies were conducted in stage 3 and are the subject of the following discussion, which summarizes the findings of a report prepared by a consulting firm under contract to the St. Paul District.

Approximately 850 acres of the city (figure 29) is served by a combined sewer system which collects both sanitary waste and stormwater drainage. During dry weather or small runoff events, the flow in the combined sewers is pumped through a main interceptor to the wastewater treatment lagoons. During larger runoff events, pump station capacities are exceeded, and combined sewer overflows discharge directly into the Red River.

These pollutants could be adversely affecting the river ecology and various uses, such as recreation, for which the river environment might otherwise be available. The extent of these impacts cannot be quantified at this time primarily because the lack of reliable field data in the Grand Forks area makes water quality modeling impracticable. Similarly, benefits from alternatives that reduce the quantity of pollutants discharged into the river cannot be quantified.

An undesirable public health hazard exists because combined sewer outfalls discharge directly into the city's water supply pool formed by a low-head dam located in Riverside Park. These overflows introduce



LEGEND

STUDY AREA BOUNDARY
SERVICE AREA BOUNDARY
3 SERVICE AREA NUMBER

fecal coliforms (an indicator of possible pathogenic organisms associated with fecal waste), turbidity, grease and oils, and various chemicals and heavy metals into the community's drinking water source. Furthermore, combined sewer backup floods basements with this same polluted flow, presenting another public health risk for those who may contact the untreated wastes.

The city has already initiated a phased program to separate its combined sewers (figure 30). The first phase of this program, involving service areas 3 and 4 on figure 29, is close to completion. Therefore, these two service areas have been excluded from further consideration in this study.

The existing capacities near the overflow structure of each of the four combined sewer service areas being studied are shown in table 19. The capacities are shown in cfs and the equivalent storm event (in terms of average return period) that the system could handle. Events exceeding those listed cause local flooding.

Table 19 - Combined sewer capacities

Service area	Pipe diameter (inches)	Capacity (cfs)	Allowable storm recurrence interval (years)
1	48	69	5
2	58 x 75	130	1
5 to valve	24	10	0.5
5 to lift station No. 2	48	65	0.5
6	48	65	<0.25

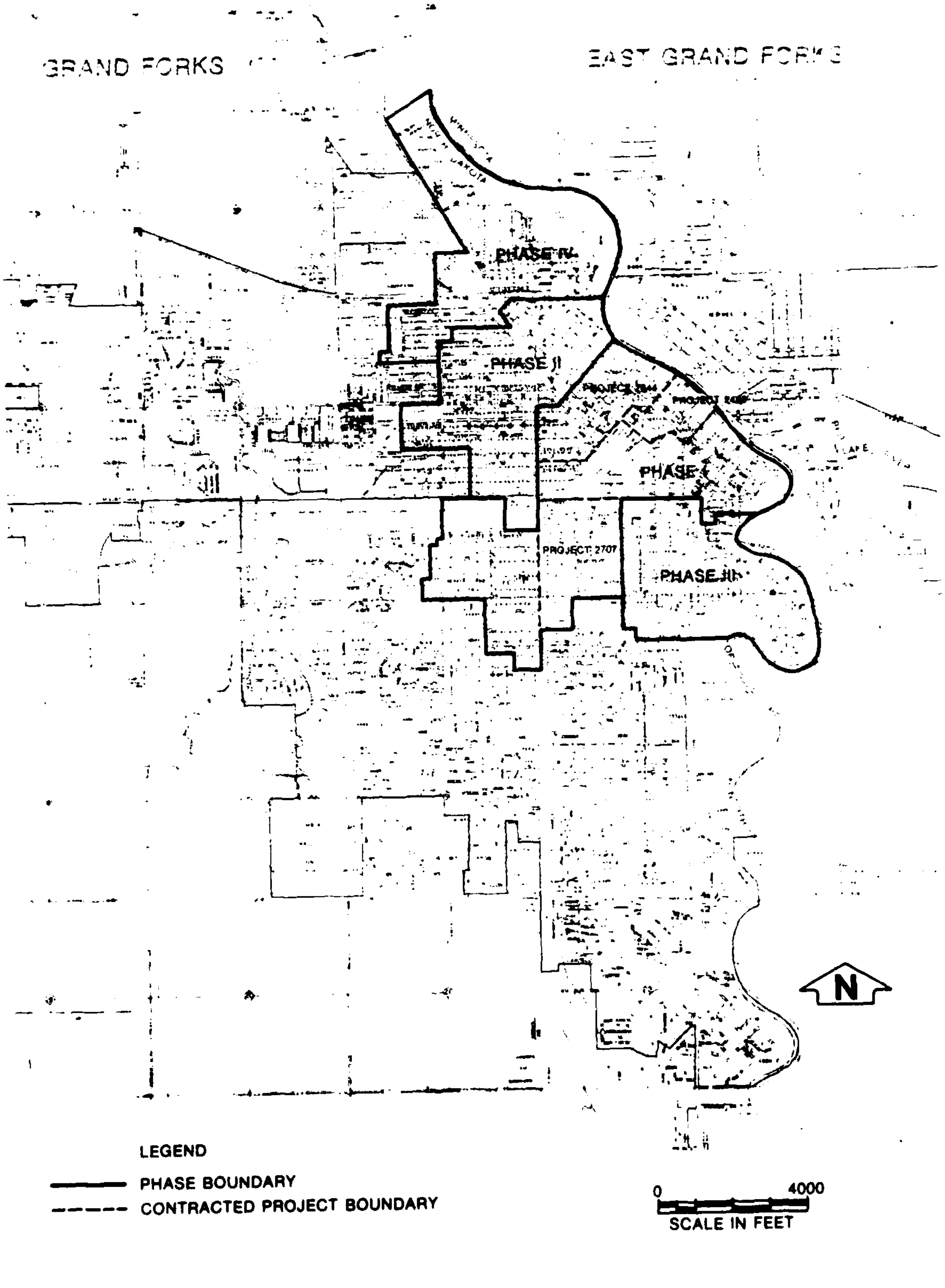


FIGURE 30 - Sewer Separation Phase Map

The existing capacities of the lift stations limit the volume of flow pumped to the wastewater treatment facilities. Table 20 shows, for each service area, the lift station's total capacity, the calculated sanitary sewage flow, and the resulting allowable storm runoff and rainfall intensity that can be handled by the lift stations. Clearly, a very small rainfall event will cause overflows; very little storm runoff from the combined area is pumped to the wastewater treatment facilities. Nearly all runoff from the 20-inch mean annual precipitation, therefore, is discharged into the river as combined sewer overflows.

Table 20 - Combined sewer lift station capacities

Service area	Lift station number	Lift station capacity (cfs)	Calculated sanitary sewage flow (cfs)	Allow storm runoff flow before overflow (cfs)	Rainfall intensity that will cause overflow (inches per hour)
1	4	0.27	0.22	0.05	<0.1
2	5	4.04	2.81	1.19	<0.1
5	2	0.45	0.06	0.39	<0.1
6	1	1.45	0.67	0.78	<0.1

The quantity of pollutants discharged into the Red River via combined sewer overflow was computed using Environmental Protection Agency figures for typical concentration values (table 21) and the calculated average annual runoff of 277 million gallons per year from the combined sewer area. Table 21 also shows the results of a sample taken at one of the Grand Forks combined sewer outfalls during a storm runoff event.

Table 21 - Combined sewer overflow quality

Item	TSS (mg/l)	BOD (mg/l)	COD(1) (mg/l)	Total nitrogen (mg/l)	PO_4-P(2) (mg/l)	Lead (mg/l)	Fecal coliforms (1,000/100 ml)
EPA published figures:							
Typical value	370	115	375	9	1.9	0.37	670
Range of values	270-540	57-230	260-480	4-17	1.3 - 2.8	0.15 - 0.6	200 - 1,200
Results from Grand Forks' monitoring of one outfall during one storm event:							
Range of values	160-960	83-239	-	-	-	-	1,500 - 2,400
Average yearly discharge in Grand Forks (lbs)(3)	855,000	266,000	866,000	20,800	4,400	850	7×10^{15}(4)

(1) Chemical oxygen demand.
(2) Total phosphorus as P.
(3) Based on EPA typical values and calculated average annual runoff from combined sewer study area.
(4) Number of organisms.

Because the combined sewer area is already largely developed, little change in land uses and population is expected; hence, future wastewater and runoff flows and pollutant loads will probably remain similar to existing levels.

A preliminary screening of alternative solutions to the combined sewer overflow problem eliminated those which clearly were impractical due to operational difficulties, environmental unacceptability, or excessively high cost. The eliminated alternatives included:

- Flow Reduction - This alternative does not include constructing separate storm or sanitary sewers, which are considered as a separate alternative. Without significant changes in land use, a significant drop in sanitary flow or characteristics is unlikely under normal circumstances. (Such a drop might be experienced during a drought, when water demands and, hence, sewer loads would be reduced voluntarily or compulsorily.) Any sanitary flow reduction would have little impact on the quantity of combined sewer discharge; however, the quality of this discharge might be less degraded. Reductions in storm runoff entering the combined sewer system could not be accomplished without increasing overland runoff, an impractical alternative for this highly developed, relatively flat area.

- Combined Relief Sewers - This alternative would reduce flooding, but continue to discharge untreated wastes into the Red River of the North. It constitutes a high cost, limited benefit alternative.

- In-System Storage - The existing system has insufficient capacity to store any significant runoff.

- Treatment in Existing Wastewater Treatment Plant - This alternative would involve temporary storage of the entire overflow volume and pumping of this volume to the city's wastewater lagoon system after the storm is over. This alternative would require not only extremely large storage facilities, but also larger lagoons to provide 180-day detention. The costs for this alternative would be prohibitive compared to other solutions.

- Filtration or Sedimentation Without Attenuating Peak Flow Rates - Facilities capable of handling peak flow rates would be prohibitively expensive. Temporary storage sufficient to reduce treatment rates (but not so large as to store the entire volume of runoff per the above alternative) was incorporated in several alternatives evaluated in more detail.

The following alternatives were evaluated in more detail. The first four are alternative combined sewer separation schemes.

- Alternative 1: new sanitary sewer system - This alternative would retain the existing combined system as a storm sewer system. The sanitary wastes would be pumped through the existing pumping stations and main interceptor to the wastewater treatment facilities. The new sanitary sewer lines (figure 31) were sized to handle flow rates based on domestic flows of 80 gpcd and infiltration rates of 10,000 gpd per mile of sewer. A peaking factor varying inversely with size of population was applied to estimate peak flow rates.

- Alternative 2: new storm sewer system - This alternative would retain the existing combined system as a sanitary sewer system. The new storm sewer lines (figure 32) were sized to handle a 10-year storm's peak flow rates computed using the Rational Formula.

- Alternative 3: partially new storm and sanitary systems - This alternative would use portions of the existing combined system where appropriate to reduce the costs of providing new storm and/or sanitary sewer lines. Generally, because larger lines are needed for a new storm sewer, it is better to convert existing combined sewers to storm sewers. In Service Area 1,

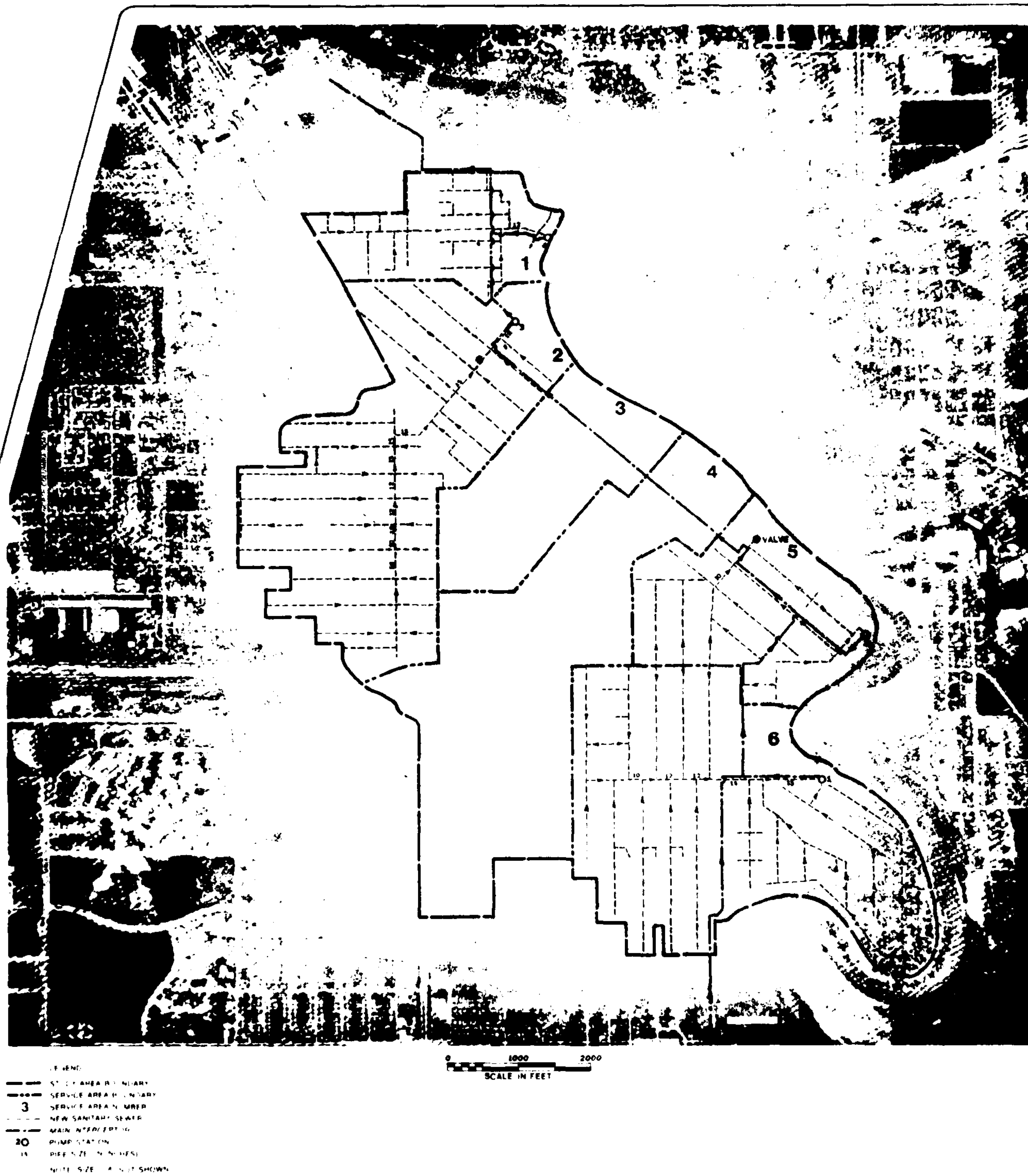


Figure 31 - Alternative 1
New Sanitary Sewer System

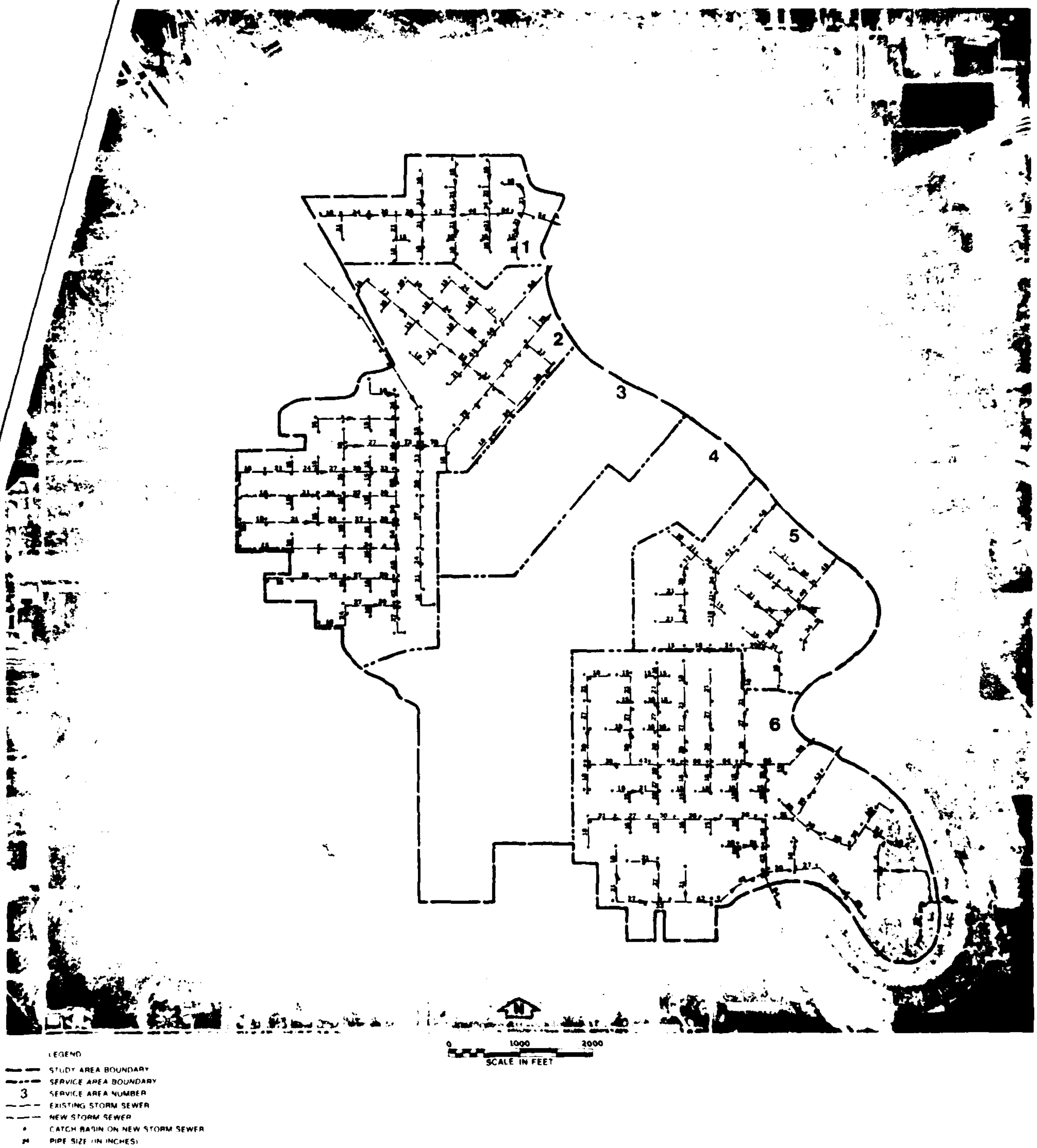


Figure 32-Alternative 2
New Storm Sewer System

this was true; therefore, this alternative was identical to the new sanitary sewer alternative. However, in Service Areas 2, 5, and 6, some of the combined sewer lines were extremely undersized. In those cases, new storm sewer lines were proposed; the undersized combined lines were generally retained instead as part of the sanitary sewer system. These plans increased the service areas' storm drainage capacities as shown in table 22; the resulting storm and sanitary systems are shown on figure 33.

Table 22 - Storm drainage improvements with partially new storm sewer system

Service area	Allowable storm recurrence interval (years)	
	Existing combined system	Proposed partially new storm sewer system
1	5	5
2	1	3
5	< 0.5	10
6	< 0.5	10

- Alternative 4: new sanitary and storm sewer systems - This alternative would totally abandon the existing combined sewers and construct new separate sanitary and storm systems. Development of this alternative essentially followed the procedures in the new sanitary sewer system and new storm sewer system alternatives, except for the abandonment of the existing system.

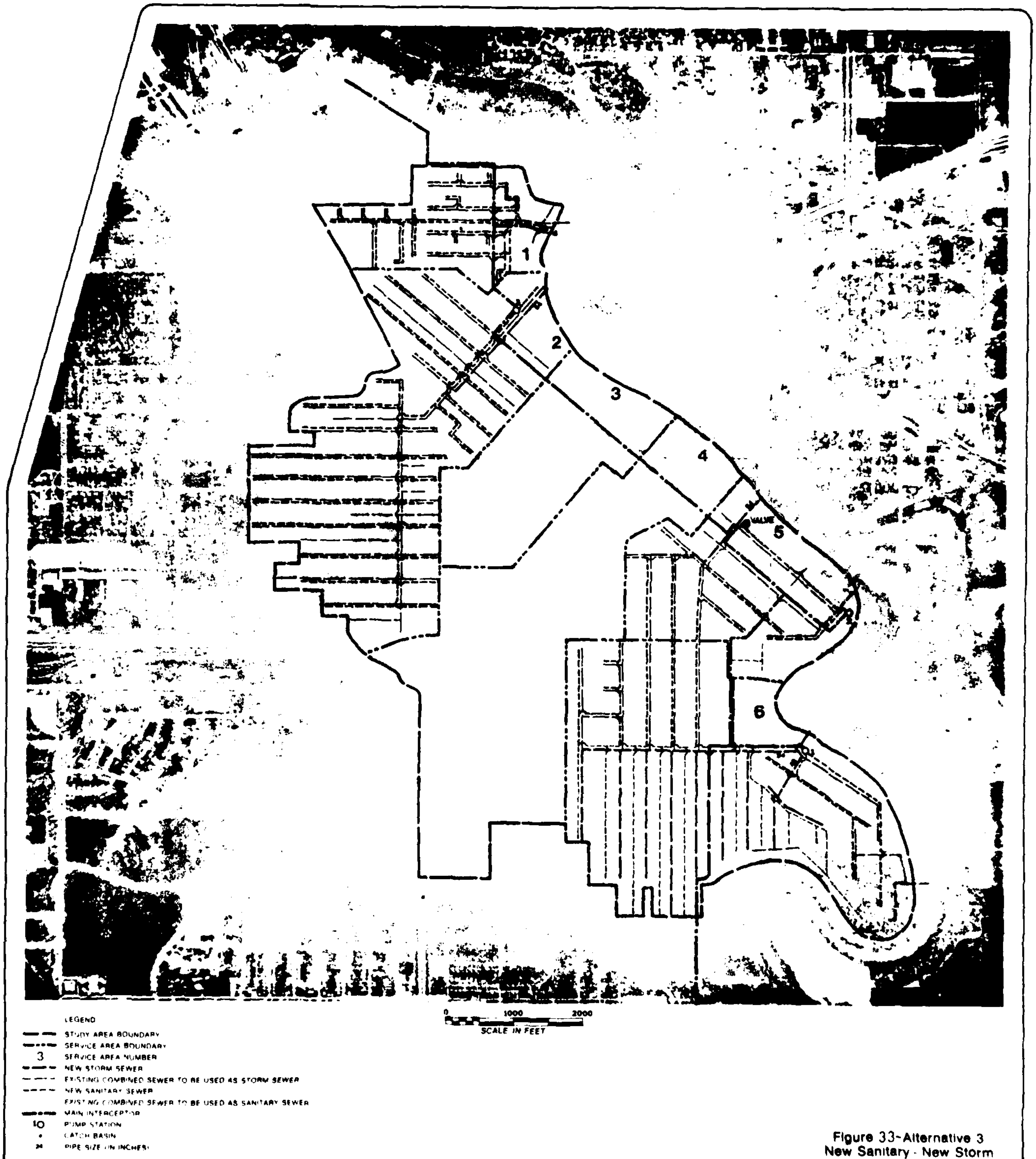


Figure 33–Alternative 3
New Sanitary - New Storm
Sewer Combination

• Alternatives 5 and 6: high-rate filtration - These alternatives would use temporary storage to attenuate peak overflow rates. The temporarily stored combined sewer overflow would be pumped at a constant, reduced flow rate through the filtration system (as shown in the schematic in figure 34) where dual media filters and, possibly, polyelectrolytes and coagulants would remove suspended solids, BOD, COD, and phosphorus. Chlorination would reduce coliform counts before discharging the water into the Red River. Two options would be available: treating the overflows at each of the service area overflows (alternative 5, figure 35) or pumping all the overflows to one site for treatment (alternative 6, figure 36).

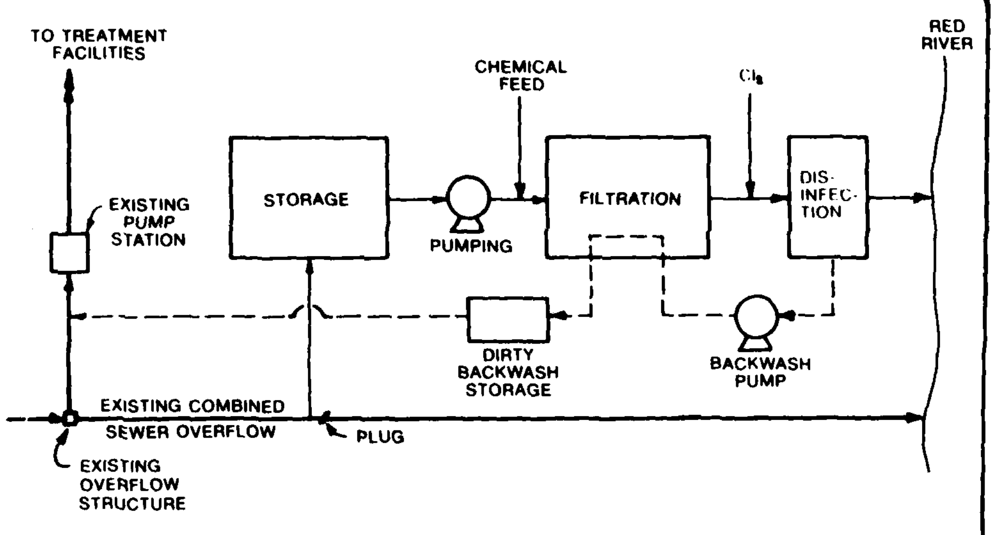


FIGURE 34 - High-Rate Filtration Schematic

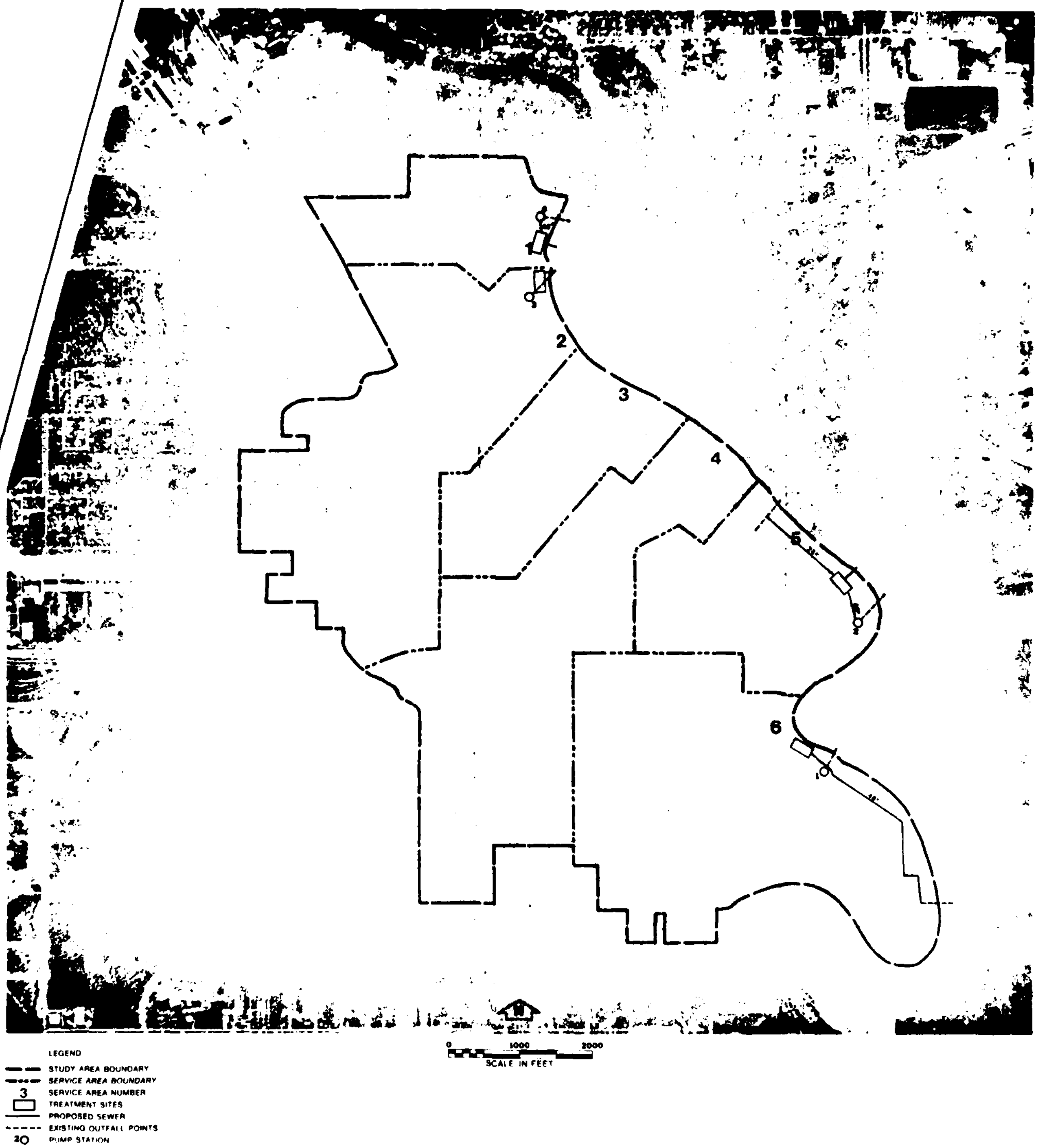


Figure 35 -
Alternatives 5, 7 and 9
Storage and Treatment
at Individual Service Areas

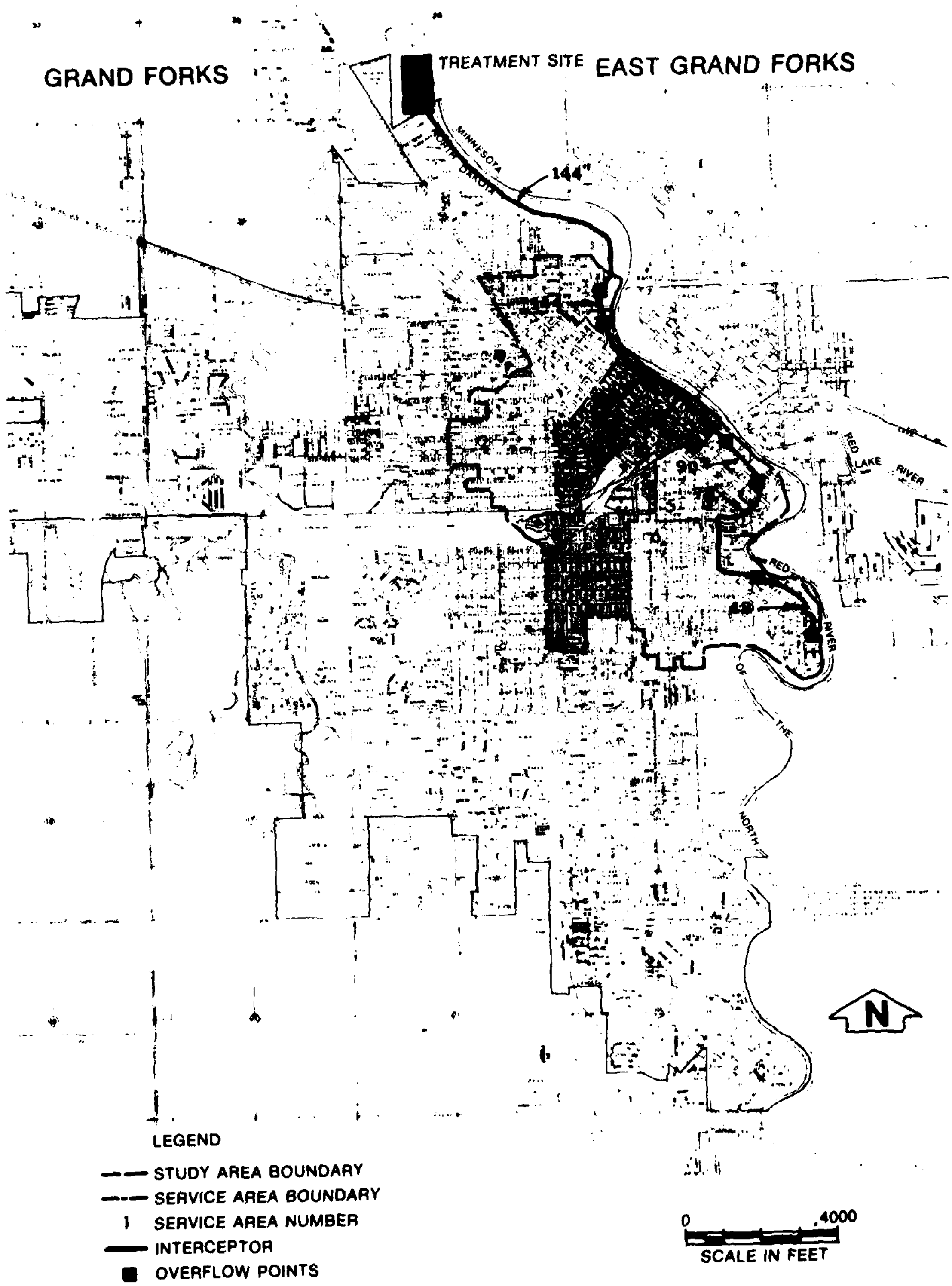


FIGURE 36 - Alternatives 6 and 8
Storage and Treatment — Single Site

- Alternatives 7 and 8: sedimentation - These alternatives would use the temporary storage facilities as sedimentation basins, with chlorination just before discharge into the river (figure 37). Like the filtration alternative, there would be two options: collect the overflows individually at each service area and treat by sedimentation (alternative 7, figure 35) or pump all overflows to one site for sedimentation treatment (alternative 8, figure 36).

- Alternative 9: swirl concentrators - The alternative that was evaluated consisted of a swirl concentrator fed by a pump at each combined sewer overflow (figure 38). Pumping would be needed to deal with two difficulties related to Grand Forks' flat topography, present sewer system, and flood conditions. First, EPA provisions call for full operational capability during floods with no less than a 10-year return period. And, second, without pumping, the head losses through the swirl concentrators would aggravate basement backups and street flooding from the combined sewers. Chlorination would be used to disinfect the water before discharge into the river. These facilities were sized to handle peak overflow rates; therefore, costs directly depended on the selected design shown. After careful analyses, the 0.25-year storm was selected as the design event providing the best balance between system costs and system performance. Although this design would allow an average of four overflow events per year to discharge untreated wastes into the Red River, about 93 percent of the total combined sewer flow would be treated. Underflow from the swirl concentrators (consisting of the removed solids and 3 to 10 percent of the inflow volume) would exceed the capacity of the existing pumping stations. Therefore, the underflow would be stored and slowly pumped to the wastewater treatment lagoon after the storm.

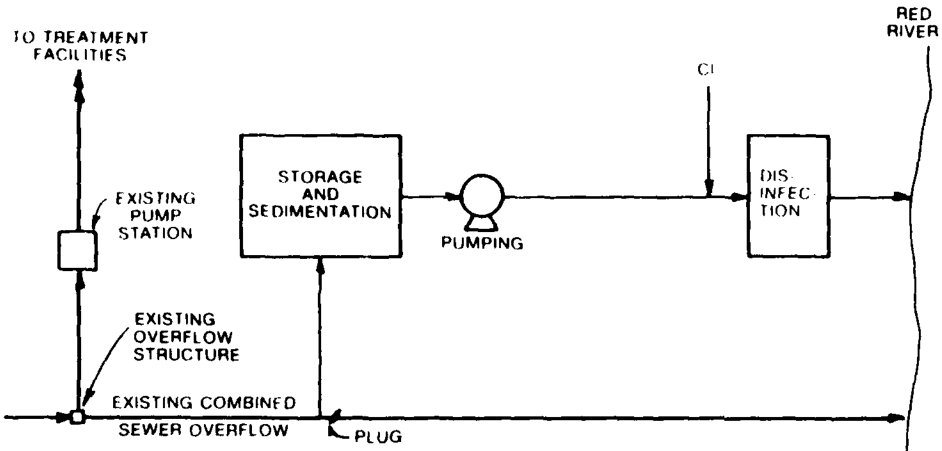


FIGURE 37 - Sedimentation Schematic

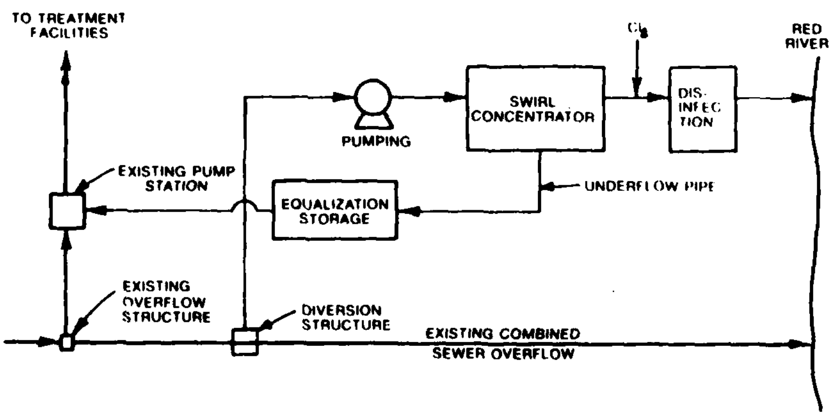


FIGURE 38 - Swirl Concentrator Schematic

• Alternative 10: relocate water intakes - Figure 39 shows the present location of the city's three water intakes in relation to the combined sewer outfalls. With the exception of the intake located upstream of the low-head dam on the Red Lake River, the city's raw water intakes are situated where untreated water from combined sewer overflows could affect the quality of the raw water being pumped to the water treatment plant.

Because of the flat slope of the Red River of the North, the pool formed by the Riverside Park low-head dam extends over 35 miles upstream from the dam. The cost of constructing and operating a raw water line to an intake upstream of the present pool would be extremely high. Also, the loss of the in-channel storage provided by the pool would reduce the reliability of the city's water supply during droughts. The Red Lake River pool would be too small to meet the demands of both Grand Forks and East Grand Forks during a serious drought. The alternative evaluated in this study would locate the intakes about 2 miles upstream of any combined sewer outfall. This alternative would retain the advantages of the pool, but reduce the probability of ingesting pollutants into the water supply system. However, this alternative only addresses one of the adverse impacts of the combined sewer overflows - it does not solve the basic problem itself and leaves other impacts unchanged.

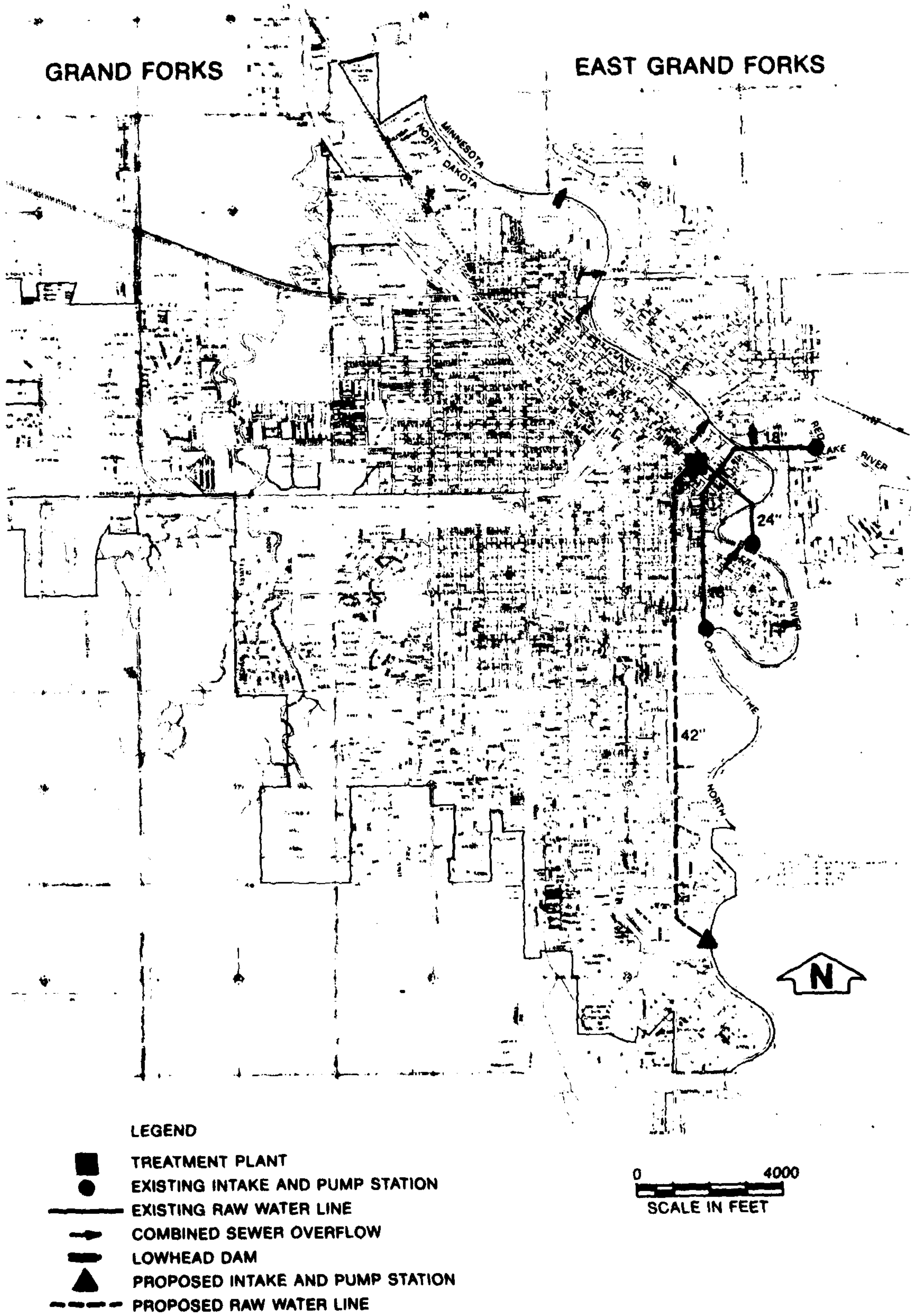


FIGURE 39 - Relocate Water Intake

- Alternative 11: collection system and source management - Because of its limited impact if implemented alone, this alternative would be considered for use in conjunction with one or more of the other alternatives. Collection system management includes adjustment of control structures, such as overflow weirs or pumping stations. Grand Forks' combined sewer system, with simple overflow weirs and undersized pumping stations, does not readily lend itself to variable control. Source management includes street cleaning, sewer flushing, and catch basin cleaning. These activities are characterized by low capital cost and high operational cost.

- Alternative 12: no action plan - Since the combined sewer area is essentially fully developed, the waste load discharged into the river would remain about the same as at present. There would be no additional costs beyond those being incurred now. This plan would not alleviate adverse impacts associated with the combined sewer overflows. The threat to public health from discharges into the city's drinking water source would not be corrected. The city would violate its National Pollutant Discharge Elimination System permit and would be subject to heavy fines.

The anticipated pollutant removal from each alternative is shown in table 23. Table 24 summarizes the environmental, social, and economic impacts of alternatives 1 through 9.

Table 23 - Estimated effect of alternatives on pollutant discharges

Alternative	Estimated percent removal of given pollutant		
	BOD	TSS	Fecal coliforms
1 - New sanitary sewer system	80	(1)	95-100
2 - New storm sewer system	80	(1)	95-100
3 - Partially new storm and sanitary systems	80	(1)	95-100
4 - New sanitary and storm systems	80	(1)	95-100
5 - High-rate filtration at each service area	75-85	90-95	100
6 - High-rate filtration at single site	75-85	90-95	100
7 - Sedimentation at each service area	50-60	75-85	100
8 - Sedimentation at single site	50-60	75-85	100
9 - Swirl concentrators	25-45	20-50	100
10 - Relocate water intakes	0	0	0
11 - Collection system and source management	5	13	0
12 - No action	0	0	0

(1) Because first flush of storm runoff solids would no longer be diverted to wastewater treatment plant, TSS may not be decreased.

Table 24 - Impact assessment

Impact	No Action	Sewer Separation Alternatives 1, 2, 3, & 4	End-of-Pipe Treatment Alternatives 5, 7, & 9	Regionalized Collection and Treatment Alternatives [illegible] & 8
Environmental				
Land	No effect.	No effect.	Land required downtown.	Up to 15 acres required.
Natural Resources	No effect.	Consumptive use of energy during construction.	Consumptive use of energy during construction, for pumping and chemicals for disinfection.	Consumptive use of energy during consutruction, for pumping and and chemicals for disinfection.
Man-made Resources	No effect.	Alternatives 1, 2, & 3 utilize existing sewer.	No effect.	No effect.
Water Quality	No change.	Improved. May be degraded during construction.	Improved. May be degraded during construction.	Improved. May be degraded during construction.
Air Quality	No effect.	Increased dust during construction.	Increased dust during construction.	Increased dust during construction.
Wildlife	No effect.	Disturbed during construction.	Disturbed during construction.	Disturbed during construction.
Hydrological	No change.	Slight reduction hydraulic load to sewage lagoon.	No change.	No change.
Public Health	No change.	May improve.	No change.	No change.
Social				
Noise	No effect.	Increased during construction.	Increased during construction.	Increased during construction.
Displacement of People	No effect.	No effect.	Possible, depends on site.	No effect.
Aesthetics	No change.	Eliminates basement flooding. *Alternatives* 2, 3, & 4 reduce street flooding.	Declined.	Declined.
Historical & Archaeological	No effect.	No effect.	No effect.	No known effect.
Transportation	No change.	Increased & disrupted during construction.	Increased & disrupted during construction.	Increased & disrupted during construction.
Institutional Relationships	No effect.	No change.	No change.	No effect.
Community Cohesion	No effect.	May improve.	No effect.	No effect.
Community Growth	No effect.	No effect.	No effect.	No effect.
Public Acceptance	No change.	Improved.	Declined.	Declined.
Economic				
Public Facilities	No effect.	No effect.	No effect.	No effect.
Public Services	No change.	Improved.	No change.	No change.
Employment	No effect.	Increased during construction.	Increased during construction and for operation of facilities.	Increased during construction and for operation of facilities.
Business & Industrial Activity	No change.	Disrupted during construction.	No change.	No change.
Tax Revenues	No effect.	Slight increase.	Decreased.	Decreased.
Property Values	No change.	Improved.	Decreased locally.	Decreased locally.

Source: Stanley Consultants

Cost estimates for each alternative were prepared for each service area to permit the selection of the optimum combination of alternatives for the overall study area. These estimates covered construction, operation and maintenance, and salvage values. Construction costs for sewer systems were based on May 1979 prices using manufacturer information and recent bids on similar work in Grand Forks. Costs for treatment works were based on cost curves and published unit cost data. A factor of 20 percent was added to the construction costs to cover contingencies, engineering, legal, and administrative expenses. Table 25 shows each alternative's estimated first and average annual costs in each of the four service areas; equivalent annual costs are based on the total present worth (which factors in salvage value and annual operation and maintenance costs) amortized over a 20-year planning period at a 6 7/8-percent interest rate. Table 25 also shows the estimated annual BOD removed and the unit cost per pound of BOD removed.

Table 25 - Alternatives' cost estimates for each service area

Alternative	Service area	Total initial cost ($1,000)	Operation and maintenance ($1,000/year)	Equivalent annual cost ($1,000/year)	Estimated BOD removal (1,000 pounds/year)	Unit cost for BOD removal ($/pound BOD)
1 - New sanitary sewer system	1	1,625	3	135	22	6.14
	2	5,474	9	454	77	5.90
	5	2,110	3	174	35	4.97
	6	4,763	7	394	79	4.99
2 - New storm sewer system	1	1,744	5	147	22	6.68
	2	7,136	17	598	77	7.77
	5	2,044	5	171	35	4.89
	6	6,123	12	510	79	6.46
3 - Partially new storm and sanitary systems	1	1,625	3	135	22	6.14
	2	6,089	9	503	77	6.53
	5	2,486	3	205	35	5.86
	6	8,087	9	666	79	8.43
4 - New sanitary and storm systems	1	2,954	3	243	22	11.05
	2	11,234	9	921	77	11.96
	5	3,727	3	305	35	8.71
	6	9,647	8	791	79	10.01
5 - High-rate filtration at each service area	1	3,238	98	368	21	17.52
	2	7,793	271	922	72	12.81
	5	5,012	139	557	33	16.88
	6	9,487	289	1,080	74	14.59
6 - High-rate filtration at single site	-	36,125	214	3,076	200	15.38
7 - Sedimentation at each service area	1	2,951	79	325	14	23.21
	2	6,854	206	779	48	16.23
	5	4,571	109	490	22	22.27
	6	8,515	222	932	49	19.02
8 - Sedimentation at single site	-	34,986	142	2,911	133	21.89
9 - Swirl concentrators	1	2,230	71	260	10	26.00
	2	4,918	168	585	35	16.71
	5	3,222	94	366	16	22.88
	6	6,329	179	714	38	18.79
10 - Collection system and source management	-	120	18	35	14	2.50
11 - Relocate water intakes	-	3,559	66	356	0	NA
12 - No action	-	0	0	0	0	NA

The final plan is comprised of one alternative selected as best for each service area on the basis of careful consideration of environmental, social, economic, and institutional factors. The considerations behind the selections are discussed below:

- Service Area 1 - This service area has an adequate existing storm flow system. Hence, the needs of this service area and the overall study area would be best met by a new sanitary system (alternative 1), which table 25 shows is most cost effective and which table 24 shows has more positive environmental, social, and economic impacts than end-of-pipe treatment or regionalized collection and treatment.

- Service Area 2 - Alternative 1 (a new sanitary system) is the most cost effective; but, because the existing combined sewers provide a low capacity for carrying storm runoff, street flooding could remain a serious problem with this alternative. Alternative 3, the next most cost-effective alternative, is recommended instead; this alternative includes a new sanitary sewer plus a new storm sewer line to provide relief capacity for inadequate portions of the existing combined sewer system to be used for storm sewer service.

- Service Area 5 - Alternative 2 (new storm sewer system) is recommended to provide an adequate storm runoff capacity; the combined sewer appears capable of providing adequate sanitary service. This alternative is the least costly and ranked favorably in terms of environmental and social impacts.

- Service Area 6 - Alternative 1 is least costly; but, because the existing combined sewer has an inadequate storm runoff capacity, street flooding problems will continue. Alternative 2 would provide the needed runoff capacity and is the second most cost-effective system, but costs nearly $1.4 million more. Alternative 1 is recommended, but public hearings may disclose a strong public sentiment for spending the extra money needed to construct alternative 2 to also solve the street flooding problems.

Table 26 and figure 40 show the overall recommended plan.

Table 26 - Selected plan

Service area	Selected alternative	Total initial cost ($1,000)	Operation and maintenance cost ($/year)
1	1	1,625	2,740
2	3	6,089	9,180
5	2	2,044	5,280
6	1	4,763	6,550
Total		14,521	23,750

Implementation steps and the estimated timetable are discussed below. It is assumed that review agencies will act promptly and affirmatively at each step.

1. The city should submit the step 2 grant application for review by the North Dakota State Department of Health and Environmental Protection Agency. Approval anticipated by mid-1980.

2. Prepare plans and specifications for the selected plan. Completion in approximately 1 year after step 2 grant is approved, say by mid-1981.

3. Submit plans and specifications and the step 3 grant application to the North Dakota State Department of Health and Environmental Protection Agency for review. Approval anticipated by the end of 1981.

4. Bidding and award of construction contract. Construction anticipated to begin in early 1982.

If the city's applications are approved, Federal grants should cover 75 percent of the pollution control portion of the project. The local share would include the remaining 25 percent of the pollution control portion of the costs plus 100 percent of any costs allocated to flood control. The city would also be responsible for operation and maintenance of the system, estimated to cost about $23,750 per year.

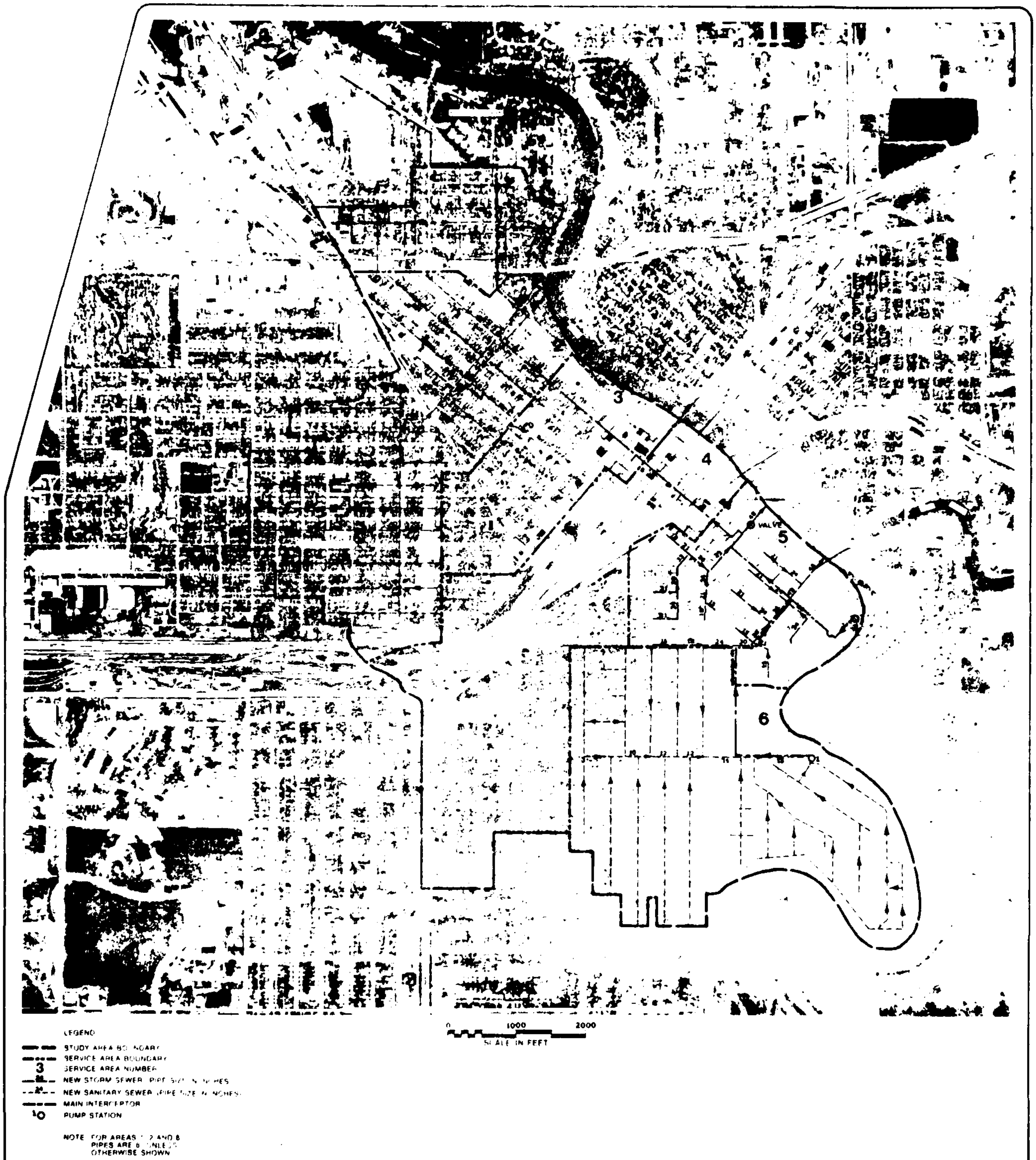


Figure 40 - Selected Plan

PUBLIC INVOLVEMENT

The public is defined as any affected or interested non-Corps of Engineers entity (including other Federal, regional, State, and local government entities and officials; public and private organizations; and individuals.

The public involvement program was an important part of the study. The overall goal of the program was to involve the public as fully as practicable in the planning process. Several complementary public involvement activities were used to encourage public participation and provide a forum for communication between the public and the planners. The activities included meetings, written materials, workshops, and displays.

The uses and scheduling of the public involvement activities were established by the needs of study participants and the planning process. As the urban study progressed, the public involvement program evolved. Stage 1 focused on the theme of problem identification. During this stage, a highly visible and intensive public relations program concentrated on reaching different segments of the public to gather information, views, and ideas regarding problems, needs, and concerns of the communities. By stage 2, those agencies and groups interested in actively participating in the urban study's planning process had been identified, and most of the public involvement effort focused on these participants. Alternative solutions were formulated and presented to interested segments of the public to get feedback for iteration of the alternatives. In stage 3, the focus was on developing detailed plans of feasible alternatives. The public involvement activities toward the end of the urban study concentrated on releasing and reporting the study findings, conclusions, and recommendations.

The reciprocal influence between the urban study process and the public not only generated input to the study, but also led to related studies of interest and influenced other planning efforts in the communities. For instance, Grand Forks and East Grand Forks have used the social and environmental inventory (which is in the Background Information Appendix) in their comprehensive planning activities.

The urban study was instrumental in developing the Grand Forks combined sewer overflow water quality monitoring study. The need for this project, conducted by the city and the North Dakota State Department of Health, was first raised at an early agency committee meeting. The scope of work was drafted by the study team and revised by the North Dakota State Department of Health. Although funded and conducted by local interests, the monitoring study was an offshoot of the urban study and the results were used by the study team.

The urban study's wastewater management report relating to the Grand Forks combined sewer overflow problem was prepared in accordance with criteria satisfying step 1 of the EPA's Construction Grants Program. The city submitted the wastewater report (prepared by a consulting firm under contract to the St. Paul District) to meet the provisions of its National Pollutant Discharge Elimination System permit. The result has been step 2 money for plans and specifications for the city's sewer separation project.

A recreation study was conducted to ensure that recreational needs were given adequate consideration during the evaluation of alternative solutions to the study area's water resource problems.

The urban study also has been involved with energy conservation through the coordination and funding of a thermography study. This study comprised an infrared aerial photo survey of buildings and homes to reveal heat losses. The photographs and other energy conservation materials were displayed for public viewing.

The urban study focused considerable attention on the English Coulee area and its flood problems. Two studies - the flood control study and the urban drainage study - investigated the area from somewhat different perspectives in seeking solutions to both backwater flooding from the Red River and direct flooding from coulee runoff as experienced in 1979. Further study of flood problems in the English Coulee and Belmont Road/ Belmont Coulee portions of Grand Forks has been recommended under the Corps' small flood control continuing authority. This authority offers a quicker route through the study process to eventual construction. The work completed under the urban study will further expedite the feasibility investigations.

The urban study reaffirmed the viability of East Grand Forks' authorized flood control project and recommended further investigation under the appropriate postauthorization study authority. As of this writing, the recommended investigation is under way.

Flood emergency plans of action were developed for both Grand Forks and East Grand Forks with the assistance of city officials and the local flood fight leadership. Manuals were prepared outlining preflood preparations, flood fight organization, and postflood cleanup. These manuals were backed up with informational materials - pamphlets and slide shows - for use by the cities in acquainting the public with their flood fight and evacuation plans and in training flood fight personnel. This "software" approach to addressing the cities' flood problems provided welcome, valuable assistance in the absence of a complete structural solution to their flood problems. If permanent flood control measures are developed through the ongoing Corps studies, the flood emergency plans can be revised by the communities to reflect the new circumstances.

Another significant spin-off study was the low-flow investigation. This investigation was an offshoot of the water supply study and evaluated drought conditions in the Red and Red Lake Rivers in relation to projected water withdrawals for municipal, industrial, and agricultural uses.

The water supply and low-flow investigations also prompted consideration of water conservation measures and development of an emergency plan for droughts more severe than the design 50-year event. The five-stage emergency plan was adopted by Grand Forks during a severe drought in 1979.

Pamphlets and professionally narrated slide shows were prepared to describe the overall urban study effort and each of the major topics - flood control and urban drainage, flood emergency plans of action, water supply, and wastewater management - and given to the cities. These materials have already been used in city planning and council meetings; and their value for advising residents of development plans, city and individual flood fight measures, etc., is unquestioned. Copies of the final urban study reports have been provided to the cities and area libraries for reference by local interests.

03-